Instruments

IE MAGAZINE of MEASUREMENT and CONTROL

VOL. 23 MARCH 1950 NO. 3

LUDING THE *Journal of the Instrument Society of America*

D THE *Journal of the Southern California Meter Association*

Monsanto Instrument Supervisor V. A. Riggio (left) who won First Prize in *Instruments'* contest (for describing how he saved $1600 per valve installation) discusses details with J. E. O'Keefe, Plant "B" Sup't of Maintenance and Construction (see pages 235 and 236).

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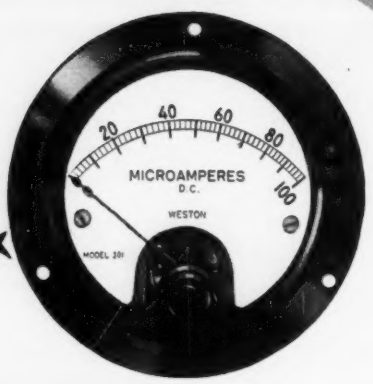

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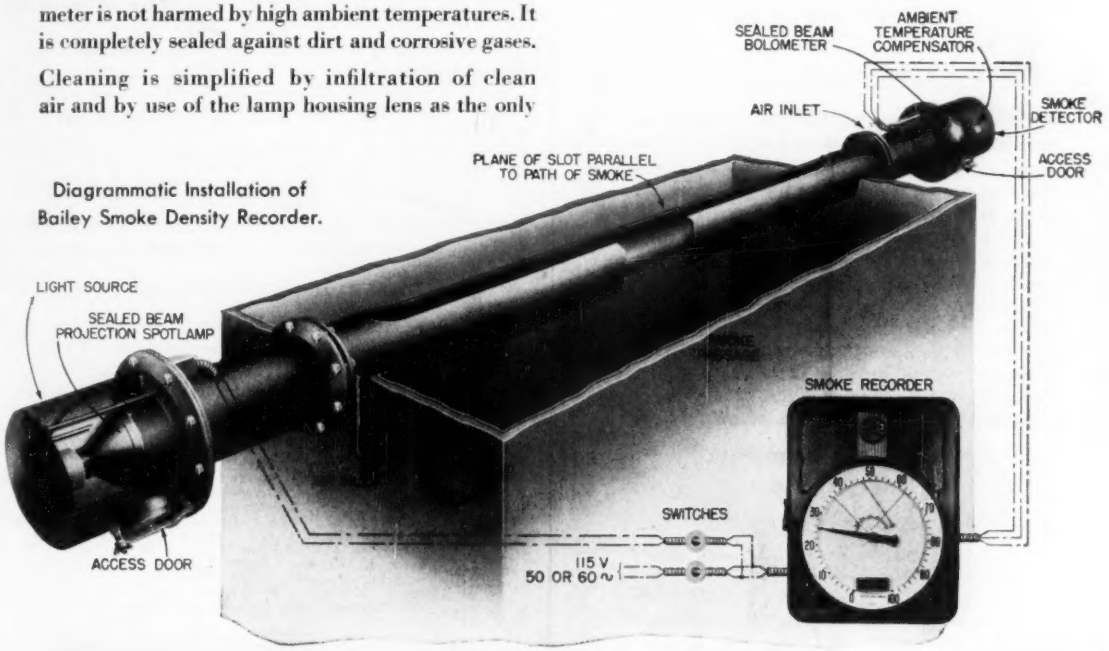

Diagrammatic Installation of Bailey Smoke Density Recorder.

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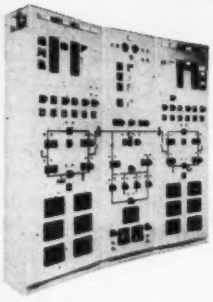

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Instruments

Vol. 23 **MARCH 1950** No. 3

SPECIAL FEATURE—PRIZE CONTEST

Editorial and complete list of winners 235

First Prize—Saving $1600 per Valve Installation 236
By V. A. Riggio

Second Prize—Increasing Furnace Production 236
By M. A. Embertson

Third Prize—Modified Gage Eliminates Maintenance Costs 238
By E. E. Stockwell

Fourth Prize—Refrigeration Temperature and Pressure Control 238
By H. H. Baker

Fifth Prize—Tank-filling Control 239
By Marvin M. Fromm

Fifth Prize—Time-saving Auxiliary Instrument 240
By John A. Kell

Fifth Prize—Alterations of Hygrothermograph 241
By Will J. Worley

TECHNICAL ARTICLES

The Mass Spectrometer 242
By Kenneth E. Burmaster and Ernest C. Evans

Temperature Measurement and Control in the Process Industries 246
By David H. Fuller

THE MONTH'S NEW INSTRUMENTS 250

INSTRUMENTS ON THE MARCH

Wear Test for Lubricants.. 248 Neutron Standard 249

OTHER REGULAR FEATURES

InstruMerriment 249; Mfrs' Literature 304; Advertisers' Index 308

JOURNAL of the INSTRUMENT SOCIETY OF AMERICA

Financial Statements for Fiscal Year 1949 277

Officers and Committee Chairmen (Pictures) 279

Instrument Repairman Training Program 280
By J. H. Cuthbert

Instrument Mechanic Training 281
By Roy Johnson

JOURNAL of the SOUTHERN CALIFORNIA METER ASSOCIATION

Slide-rule Settings for Use in Measurement Work 285
By Chas J. Soyster

Automatic Controls for Air Conditioning 286
By Frank R. Fitzgerald

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Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. BEHAR, Editor

IN this issue are printed all seven contest entries that won cash prizes. It is safe to predict that you will read most of them—perhaps all—and that many of you will then say to yourselves: "If I had sent in an entry on that XYZ job, I might have won a prize!" This is so because our subscribers possess, as a group, a tremendous quantity of ideas that have not been published—ideas that SHOULD be published in *Instruments* for the common benefit. Therefore, we remind all subscribers that *Instruments* pays a minimum of $5.00 for brief "Shop Kinks." This offer began before Pearl Harbor; and many shop kinks (and lab kinks and field-installation kinks) were published during the war—which they helped win. So please keep in mind this standing offer. The minimum is $5.00 for a manuscript without illustrations; we have paid up to $20.00 for illustrated and well-written pieces. Address Shop Kinks Department, *Instruments*, 921 Ridge Ave., Pittsburgh 12, Pa. Type double-space, use India ink for diagrams (blueprints don't reproduce) and observe other usual rules.

Another comment we can't resist making is that hundreds of instrument-company sales engineers must be modest fellows. We refer, of course, to those who could have sent in reports of saving costs for their customers—entries like the one that won Second Prize. This goes for advertising managers, too: we're sure that some of them purposely refrained from submitting amazing stories of huge savings, illustrated with excellent photographs, in order to give non-professional writers a chance.

We're sure, also, that the Judges' First Prize choice will be universally approved. By the way, when we notified Mr. Riggio and exchanged letters with him about a photograph for *Instruments*, and various other details, we learned that the savings are really sensational: actually $3002.00 per valve installation PER YEAR. About the photograph he wrote to us: "Mr. James E. O'Keefe is holding the Micarta plug for a 2-inch Saran-lined tee valve with a reduced port of 1 inch. The valve on the test stand is a 1½-inch Saran-lined tee valve with an Annin air-operated topwork assembly."

FIRST PRIZE ($200)

V. A. RIGGIO, 20 Green Acres, St. Louis 15, Mo. "Saving $1600 per Valve Installation."

SECOND PRIZE ($100)

M. A. EMBERTSON, Wheelco Instruments Co., Chicago, Ill., "Automatic Control Helps to Save the Cost of One 50-foot Furnace by Increasing Production of Others."

THIRD PRIZE ($75)

E. E. STOCKWELL, Baton Rouge, La., "Modified Gage Eliminates Maintenance Costs."

FOURTH PRIZE ($50)

H. H. BAKER, Instrument Dep't, Arabian American Oil Co., Dhahran, Saudi Arabia, "Refrigeration Temperature and Pressure Control."

FIFTH PRIZES ($25 each) (Alphabetical order)

M. M. FROMM, Greensburg, Pa., "Tank-filling Control Ends Costly Spillage-waste, Speeds Operations."

JOHN A. KELL, Analysis and Test Engineer, Chesapeake & Ohio Railway Co., "A Time-saving Auxiliary Instrument."

WILL J. WORLEY, Ass't Prof. of Theoretical & Applied Mechanics, University of Illinois, Urbana, Ill., "Slight Alterations of a Standard Hygrothermograph Cuts Costs."

HONORABLE MENTIONS (Alphabetical order) (To be published in later issues)

T. M. BERRY, General Electric Co., Schenectady, N. Y., "Automatic Optical Contour Follower Cuts Cost of Producing Airfoil Master Patterns."

A. L. CHAPLIN, Proctor, W. Va., "Control Installation Pays for Itself in One Week."

P. W. DEWEY, Research Dep't, Standard Oil Co., Whiting, Ind., "Automatic X-Y Coordinate Millivolt Recorder."

R. L. GALLEY, North American Aviation, Inc., Los Angeles, Calif., "Controlling Costs in Production and Distribution of Utility Fluids."

PAUL GRODZINSKI, Industrial Diamond Information Bureau, London, England, "Indentation Hardness Tester."

T. R. HAND, Special Products Div., Schenectady, and R. C. MILES, Quality Control Engineer, Erie Works, General Electric Co., "Quality Control Indicator—Management's Tool to Cut Production Costs."

C. C. HARD AF SEGERSTAD, Chief Engineer, The Sandvik Steel Works Co., Ltd., Sandviken, Sweden, "Pneumatic Bridge or Delta System."

J. A. HARTNETT, Honeywell-Brown Ltd., Greenford, Middlesex, England, "Automatic Water Softener Control."

H. I. NORTON, Needham, Mass., "Fluid Proportioning."

V. A. RIGGIO, St. Louis, Mo., "Micarta Orifice Plates."

V. A. RIGGIO, St. Louis, Mo., "Modified Air Booster."

V. A. RIGGIO, St. Louis, Mo., "Determining Valve Size to Fit a Control Problem."

HERMAN RUEGER, Lancaster, Pa., "Flaw Locator."

HERMAN RUEGER, Lancaster, Pa., "Immersed-object Polariscope."

VICTOR STUART, Knopf Instrument Co., Jersey City, N. J., "Travelogs."

EUGENE H. WOODMAN, Vicksburg, Miss., "Electric Counting, etc."

Prize-winning articles in *Instruments'* contest. See editorial on preceding page.

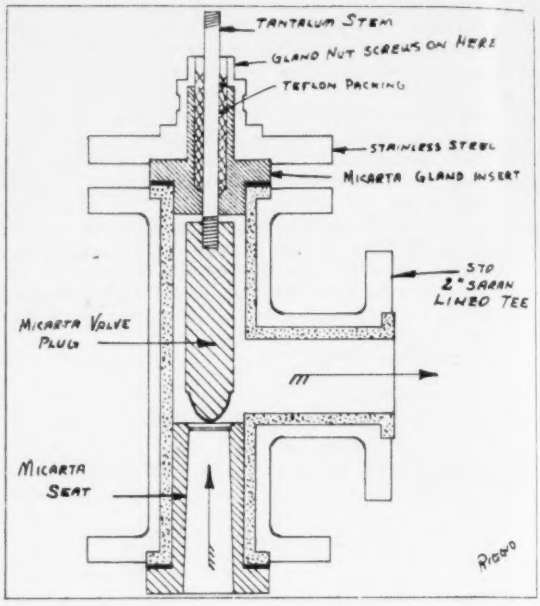
FIRST PRIZE ($200)
SAVING $1600 PER VALVE INSTALLATION

By V. A. RIGGIO, 20 Green Acres, St. Louis 15, Mo.*

WHEN our nickel valves corroded so that we had no control over an alkylated liquor, we tried valve bodies of various alloys but with no reasonable success. Experiencing success with Micarta and Saran (see my other contest entries) I decided to make one of Saran and Micarta. The body is made from a standard 2-inch flanged Saran tee with Micarta seat and plug, with a top flange machined to fit a Fisher or Foxboro or Annin top-work assembly.

Note on Cost Cutting: When computing valve life and maintenance of other valve bodies, we found that this one has saved us approximately $1600 per valve installation, based on figures we have kept on other good alloy valve bodies.

No wear or corrosion is evident on three of these valves after more than six months' service.



*EDITOR'S NOTE.—This address appeared on all four of Mr. Riggio's Contest entries. AFTER this entry won First Prize, we corresponded with Mr. Riggio and learned that he is a Monsanto plant Instrument Supervisor. The picture on the front cover of this issue of *Instruments* did NOT come with this Contest entry: we requested it AFTER this entry had won the First Prize. See preceding page for more details.—M. F. BEHAR

SECOND PRIZE ($100)
AUTOMATIC CONTROL HELPS *to* SAVE *the* COST *of* ONE FURNACE *by* INCREASING PRODUCTION *of* OTHERS

By M. A. EMBERTSON, Wheelco Instruments Co., Chicago, Illinois

RESULTS achieved through the installation of a new wire patenting furnace, complete with full automatic control equipment, in the plant of Macwhyte Company, Kenosha, Wisconsin, have far exceeded all expectations from the standpoint of economy and increased production capacity.

The Macwhyte Company was established in 1896 as the Macomber and Whyte Wire Rope Company and has consistently been one of the leaders in the manufacture of wire rope and wire products. Such items as aircraft cord and strand, braided wire rope slings, elevator cables and wire rope for general hoisting purposes are just a few of the many and varied types of wire rope produced by this company. Familiar to industry are such Macwhyte trade names as "Iron Grade," "Traction Steel," "Mild Plow," "Plow Steel" and "Monarch Whyte Strand" Improved Plow Steel—this last having the best tensile strength.

The Macwhyte Company's plant includes both a wire rope mill and a wire mill. Prior to the manufacture of rope wire it is necessary to subject the hot-rolled wire rod to a heat-treating process called patenting. The rod is then pickled at temperature ranging from 125 to 140 F., lime-coated, and baked at from 280 to 320 F., after which it is drawn to size. When the wire has finally been cold-drawn and is ready to be manufactured into rope, it is subjected to a series of rigid physical measurements and tests to determine size, section, tensile, torsion, bend, elongation, reduction in area and fatigue.

The patenting process is critical, inasmuch as it has as its purpose the obtaining of a definite type of grain structure. The new 50-foot continuous four-zone wire patenting furnace was designed and built by Macwhyte engineers, with Plant Engineer Archie Naysmith and Chief Metallurgist Walter Bloxdorf setting the specifications and supervising the job. Babcock and Wilcox firebrick was installed by R. M. Onan of Milwaukee. Each of the four heating zones is closely controlled by a Wheelco "Model 241X Xactline Capacitrol" which actuates a Barber-Colman motor to operate a variable-port North American Valve. Burners are manufactured by Eclipse Fuel Engineering Company.

The raw material consists of hot-rolled wire rod ranging in carbon content from 0.15 to 0.85 percent. The new 50-foot furnace can handle 48 strands of material at a time in sizes from 0.090 inch diameter wire up to five-sixteenths-inch diameter rods. A 30-foot two-zone furnace (also Wheelco controlled) is used for treating wire of smaller sizes and can handle 60 strands at a time.

The wire is fed into the furnace from reels (also called "swifts") where it passes through each of the four zones; there temperatures are closely main-

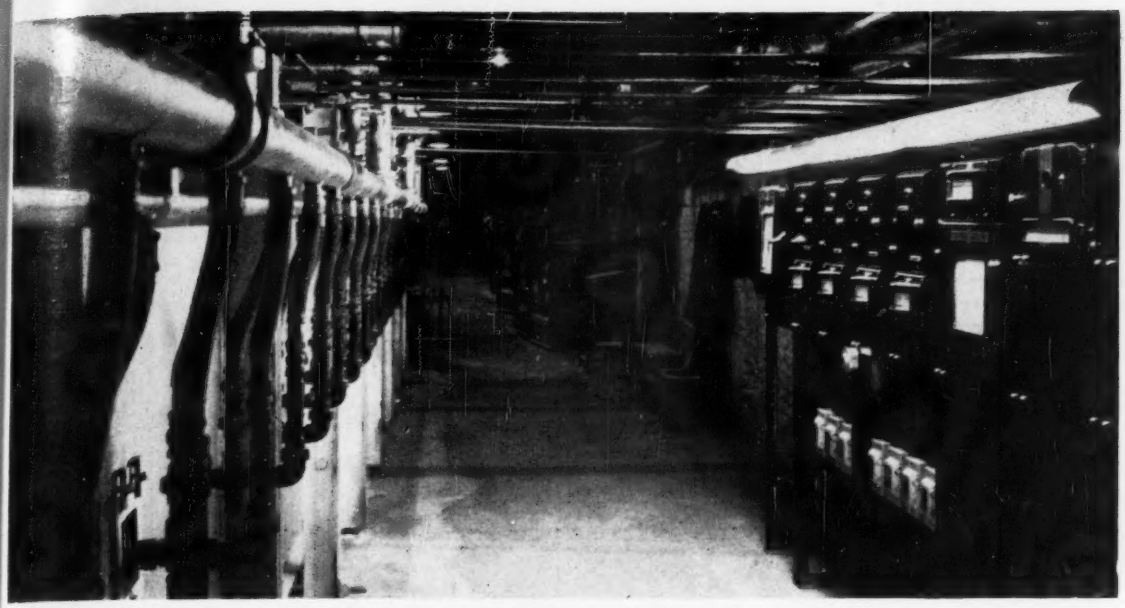


Fig. 1. View of instrument panel showing the automatic temperature controllers for four-zone continuous wire patenting furnace and electrically-heated nitrate salt bath.

tained within the range of 1775 to 1825 F. depending upon the size and quality of the wire being processed. These temperatures are also indicated on the scales (0-2000 F.) of the Capacitrols which use straight type Chromel-Alumel thermocouples as sensing units in the four zones. A recorder provides a permanent record of the heat treating operation. The desired size of the finished wire determines the number of times the stock is given the patenting treatment.

As the wire leaves the furnace it enters an electrically-heated nitrate-type salt bath, the temperature of which ranges from 950 to 1000 F., thereby providing a constant temperature transformation to develop definite grain structure and physical properties. The entering end of the salt bath is controlled by a Wheelco "Model 7001 Capacilog" indicating and controlling strip-chart recorder. This instrument controls and records the temperature sensed by an angle type thermocouple inserted into the salt bath, with an accuracy of plus-or-minus 10 F. The exit end of the salt bath is controlled by an indicating pyrometer controller. A Wheelco "Limitrol" (high temperature cut-off) will be added to the salt bath control system in the near future to provide protection against overshooting of temperature.

Motor-driven blocks, rotated through gear reducers, are used to pull the wire off of the swifts, through the furnace and salt bath, and rewind them into coil form prior to transporting on overhead conveyors to the Pickling Department.

Originally it was the intention of Macwhyte engineers to install three 50-foot furnaces and one 30-foot furnace for their patenting operation. The old furnaces had been capable of handling 1500 lbs. of wire or rod per hour.

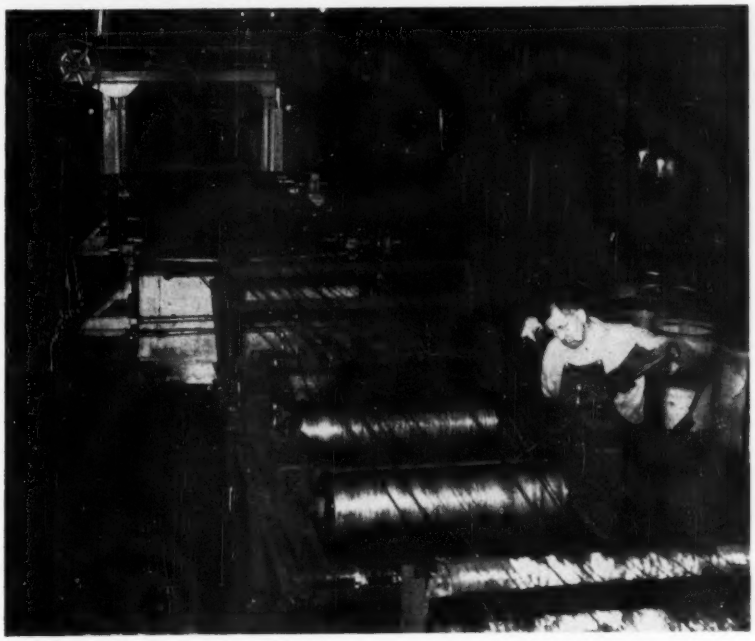


Fig. 2. Wire being pulled through patenting furnace, salt bath and wash prior to being re-wound into coil form and transported to Pickling Department.

The new 50-foot furnace with complete automatic control now turns out an almost unbelievable record of 4000 lbs. per hour. It was assumed that the new installation would perform at 35 percent efficiency; however, it has been operating for several months at 85 percent efficiency. As a result, the company will now use two 50-foot furnaces and one 30-foot furnace, thereby saving the tremendous cost of another 50-foot furnace without sacrificing production capacity in practicing this economy.

In addition to the advantages listed above, Mr. Naysmith and Mr. Bloxdorf assert that the present patenting operation is so effective that it has decreased the pickling time 30 percent. Less fuel is being consumed now than before and it is quite possible that an additional fuel saving will result when the locality is furnished with natural gas next year. The furnace is now operating on propane. Last but far from least, the patenting process with automatic controllers has been instrumental in maintaining and improving the general over-all quality of Macwhyte products.

THIRD PRIZE ($75)

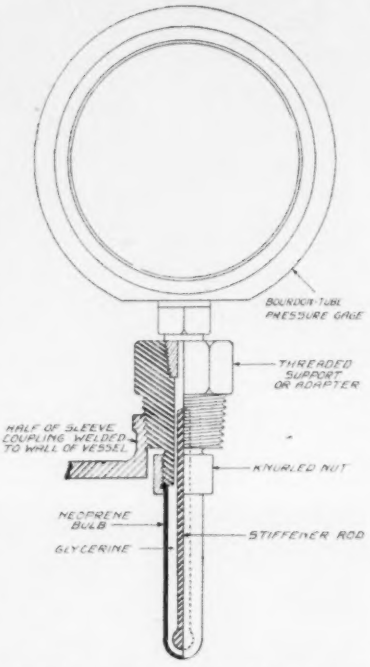
MODIFIED GAGE ELIMINATES MAINTENANCE COSTS

By E. E. STOCKWELL, Baton Rouge, Louisiana

THE operators of the chemical plant where I work require a continuous indication of the pressure of hot caustic slurry that flows in a 12-inch pipe. At first the pressure was measured by means of a Bourdon-tube pressure gage that was connected to the 12-inch pipe by a smaller pipe in the usual manner. That method was unsatisfactory and the expense of maintenance was high, because the slurry that stood and cooled in the small pipe deposited scale and other solids which soon plugged that pipe and kept the gage from working properly.

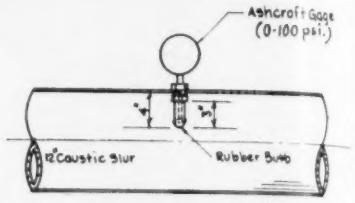
About six months ago I found that one of the commercial forms of sealed-off gages could be modified to give the desired continuous indication. The instruments referred to include the "O" Ring Seal, sold by Industrial Instrument Co., Odessa, Texas, and the No. 1073 Gage Saver, sold by Manning, Maxwell, and Moore, Inc., Bridgeport, Conn. Each consists of an ordinary pressure gage attached to a pressure-responsive member comprising a liquid-filled rubber bulb in a metal housing that the user can connect, by tubing, to any desired pressure point.

The modifications consisted in (1) eliminating the bulb housing; (2) inserting a stiffening rod into the bulb; and (3) providing a threaded supporting part between bulb and gage.



These modifications allowed the assembly to be screwed into a suitable opening in the slurry pipe so that the bulb was inside and in the hot slurry, while the gage was directly outside. The accompanying sketch shows how it was done.

One of these instruments, which was modified for me by Industrial Instrument Co., Odessa, Texas, has been in continuous service for about six months where the caustic slurry has a temperature about 205 F. and a pressure about 40 psi. No trouble from deposited solids has occurred in that time, and the gage continues to be sensitive to pressure changes.



This scheme for measuring pressures may have many applications, particularly where concentrated solutions that deposit crystals, or slurries that deposit solids, would have to be allowed to stand and cool in the commonly-used connecting pipes between vessel and gage.

FOURTH PRIZE ($50)

REFRIGERATION TEMPERATURE and PRESSURE CONTROL

By H. H. BAKER, Instrument Dep't, Aramco, Dhahran, Saudi Arabia

THE subject of this entry is the control of a large diaphragm valve with a refrigeration expansion valve, one of a type that has external equalizing connection. The one used in this problem was an Alco Freon 12-expansion valve (Type-TCL, Constant 3F, 6-ton Tubing 5).

The problem which was thus solved was to control brine in vegetable storage to maintain a temperature of 38 to 40 F., with a 1½-inch diaphragm valve.

I submit two sketches to explain how temperature and pressure were controlled with the unit which I devised. In both cases the internal equalizing hole was closed up and external connection was used. At this point we connected an instrument air reducer, the type used in air transmitters.

As the bulb has a definite pressure for each temperature, the pressure to be applied to the equalizer of the Alco-F12 expansion valve to control temperature, may be located in any refrigeration service manual of Freon 12. From this table the pressure used for checking the new unit was at 32 F. or a bath of cracked ice. The pressure given for F12 was 44.77 psia. or 30.07 psig. From this pressure must be subtracted internal spring pressure, which was set at 5 psi. in this case and closed off controlled air to main valve at 25.07 psig.

I will give a few gage pressures taken from the refrigeration service

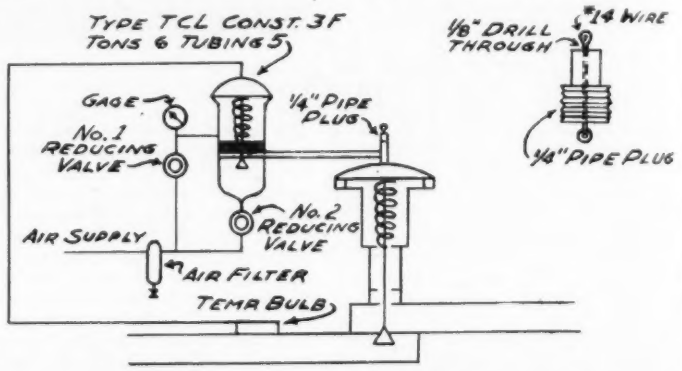


FIG. 1—TEMPERATURE INCREASE OPENS VALVE

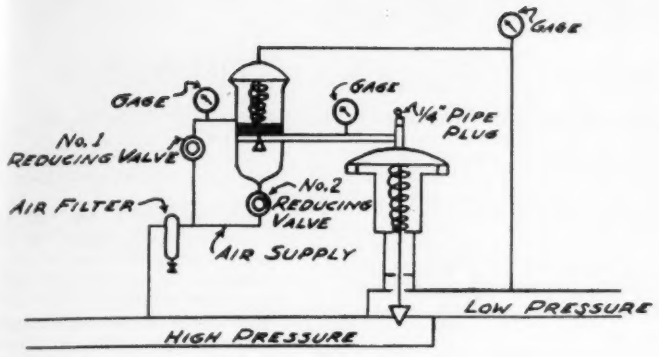


FIG. 2 – PRESSURE INCREASE SHUTS VALVE

manual: 30 F. 28.46 psig; 40 F. 36.98 psig; 50 F. 46.69 psig; etc.

Refer to Fig. 1 for temperature and to Fig. 2 for pressure.

The pressure unit was made from an old Freon-12 expansion valve the bulb of which had lost its charge of gas. We cut off the tube and soldered a quarter-inch flare half-union to the top where the bulb tube was connected; then we connected this to the line on the low side of the large diaphragm valve (which is of the type which travels fully from 3 to 15 psi. control pressure).

Two air reducers are used: No. 1 for control to equalizing side of the Alco expansion valve; No. 2 sets the air supply, so that the large valve diaphragm will never get more than 18 or 20 pounds of control air pressure.

A small orifice is placed in the quarter-inch pipe plug, drilled one-eighth inch; and we use a No. 14 gage wire through this hole to assure of not stopping up.

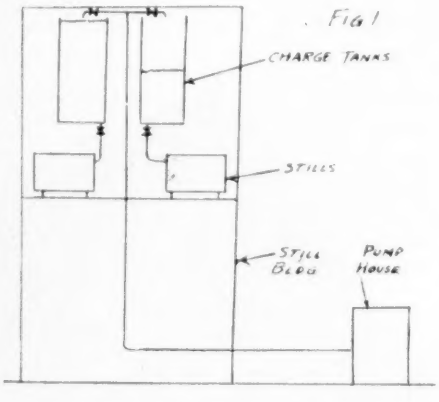
To regulate this unit, air on the lower side of the diaphragm of the Alco expansion valve is changed to increase or decrease the pressure to be controlled. No. 1 reducer is used to control equalizer pressure or change to any pressure selected.

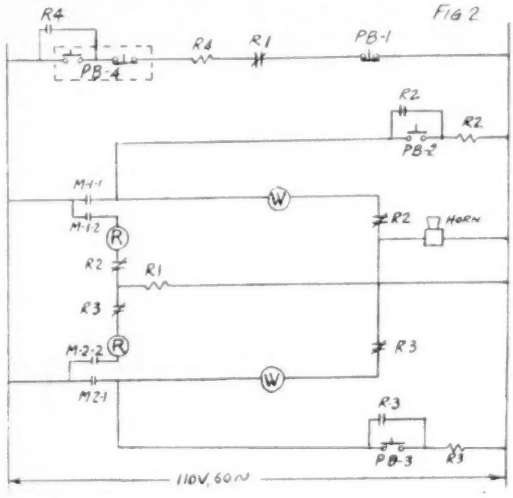
FIFTH PRIZE ($25)

TANK-FILLING CONTROL ENDS COSTLY SPILLAGE-WASTE, SPEEDS OPERATIONS

By MARVIN M. FROMM, Greensburg, Pa.

OPERATORS of batch resin stills in a chemical plant are required, in addition to their other duties, to fill vertical still charging tanks (Fig. 1). The next charge, therefore, is ready as soon as the previous bottoms are drained from the still.





On many occasions, the operator was busy elsewhere when the charge tanks were full. Quantities of resin solution, up to several hundred gallons, overflowed and had to be removed from the floor quite a few times.

To save this time and money, a safety shut-off system for two charge tanks was designed. It is shown schematically in Fig. 2. The charge pump motor starter is operated by PB-4 in the pump house. The pump can be stopped manually from there, or by PB-1 on the still floor.

At the top of each charge tank, a two-stage Schaub "Magnetrol" is mounted, with only the float ball contacting the resin solution. These are designated as M-1 and M-2, with each stage shown as a separate contact. The stages are set two inches apart. When pumping into No. 1 charge tank, for example, if stage 1 in M-1 is reached, a white light goes on and the horn sounds to remind the operator that action is required. He pushes PB-2 to silence the horn, and turns off the pump with PB-1.

If the operator is not on the floor, and stage 2 is reached, the red light goes on and relay R-1 is operated, automatically stopping the pump. When relay R-2 is operated to turn off the horn, the normally-closed R-2 contact in series with M-1-2 is opened, reclosing the R-1 contact in the pump starting circuit. This allows the pump to fill the other charge tank, with the M-2 Magnetrol ready to operate if required.

Resin must be cleaned from the float ball periodically, but the period is not critical, and the operation is easily performed, since the tanks are open on top.

FIFTH PRIZE ($25)

A TIME-SAVING AUXILIARY INSTRUMENT

By JOHN A. KELL, Analysis and Test Engineer, Chesapeake & Ohio Railway Co., Cleveland, Ohio

OUR most-used instrument is an oscillograph containing high-sensitivity galvanometers that require no amplifiers for low-frequency strain and vibration measurements. When working on passenger and freight cars this is an important consideration.

In earlier tests with this device, it was our practice to devise balancing, attenuating and calibrating circuits for each job. This work, plus the work of mounting accelerometers, displacement devices and strain gages, often took two men as long as a week's preparation. This work was sometimes done in the field, with consequent additional expense.

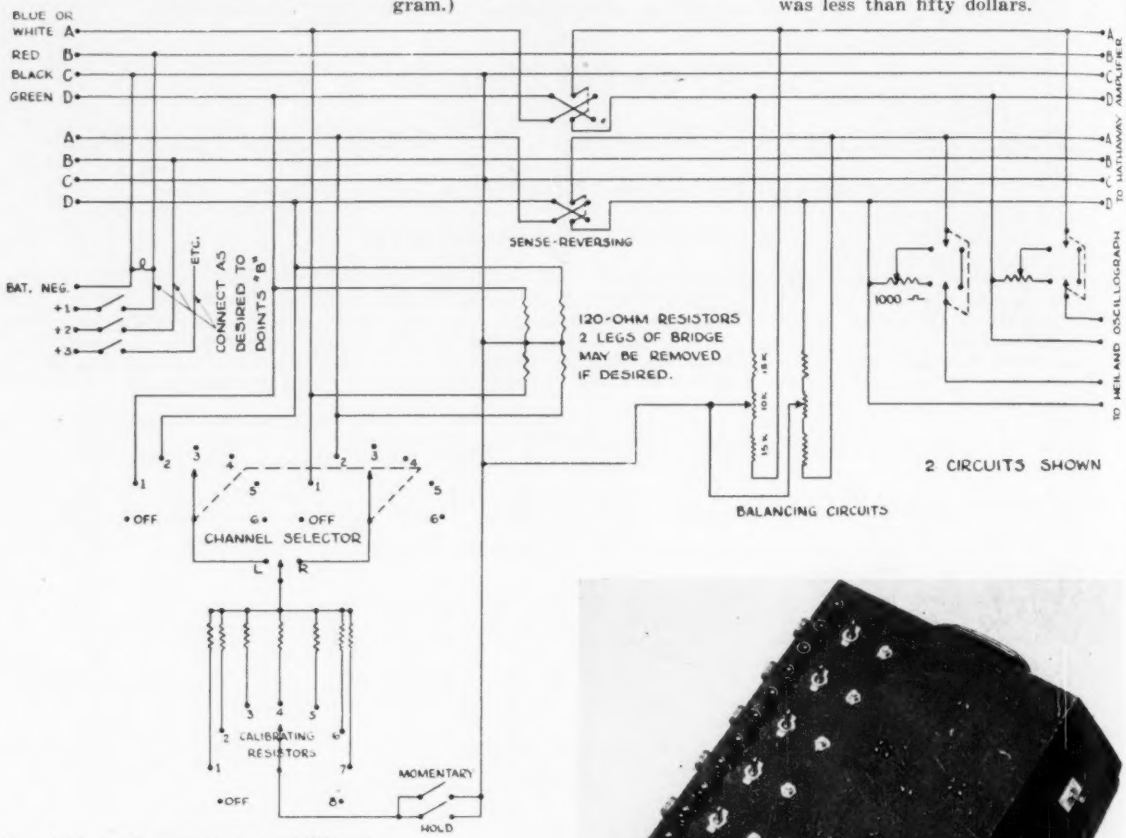
After several tests, we devised the six-channel control and calibrating unit, described herein, to work with the oscillograph. It has proved to be sufficiently flexible to take care of all our needs.

Since designing this unit, preparation for tests seldom exceeds a day since it is only necessary to devise vibration pickup mounts and apply strain gages. It has been used on eight test setups so far and no serious faults have developed. Estimated time saved is at least 30 man-days to the present. At 25 to 30 dollars a day, the instrument has paid for itself and saved the company at least 500 dollars.

The apparatus consists of six circuits designed around Wheatstone bridges. There is a means of applying any of three d-c. voltages to the six circuits, a calibrating circuit which shunts any of eight calibrating resistors across either of two adjacent legs of any of the six bridges, two legs of a 120-ohm bridge which may be removed if desired, sense-reversing switches, balancing controls and attenuators for use with the oscillograph. (See circuit diagram.)

This instrument is designed to be used also with our six-channel amplifier.

This instrument was not primarily designed to save money but rather to improve the usefulness of our instrumentation. It seems to me that, in this case, improvement of instrumentation yielded financial gains through reduction in costs of tests. This instrument has been used on freight-truck tests between Grand Rapids and Detroit, a passenger-car test on the C&NW RR, an AAR test on the IC RR, and about seven laboratory setups. Three field tests are scheduled for it during the next few weeks. The cost of the parts was less than fifty dollars.



FIFTH PRIZE ($25)
SLIGHT ALTERATIONS OF A STANDARD HYGROTHERMOGRAPH CUT COSTS

By WILL J. WORLEY, University of Illinois, Urbana, Ill.

The General Problem

FOR the past ten years we have maintained the temperature and relative humidity at 77 plus-or-minus 1 F. and 50 plus-or-minus 2 percent, respectively, in our plastics testing laboratory. A continuous record of the temperature and relative humidity has been obtained with a Friez hygrothermograph which records on a weekly chart.

Some four years ago we installed an auxiliary circular-chart type instrument. This instrument used wet- and dry-bulb liquid thermometers and contained control relays; it was used to record the wet- and dry-bulb temperatures and the relays were used to signal when the conditions were not within the control band.

The primary purpose of this recorder-controller was that of signalling when the room conditions were out of control since the Friez hygrothermograph provided a very satisfactory record of the existing conditions.

One of the difficulties with this system resulted from having to continually replenish the distilled water supply for the wet- and dry-bulb wicks and from having to replace the wicks at indefinite intervals. Tap water was found to be too high in mineral content to be used effectively. Even with distilled water, the signal system was found to operate almost as often due to running out of water, or to dirty wicks as it did due to the conditions in the room being out of control.

The distilled water had to be transported from another building, several blocks away. This further increased the cost and inconvenience of the system.

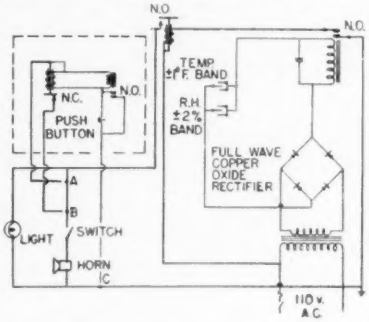
It was essential that control over the conditions in the laboratory be maintained on a twenty-four hour basis. This required an attendant to be "on call" day or night and the great number of false alarms which resulted from the above-listed causes also increased the cost due to overtime.

The major problem was thus to provide a trouble-free signal system requiring less attention than the one described above and with a minimum of new equipment.

Alterations Found Necessary

It occurred to us that the Friez hygrothermograph afforded an excellent means of signalling when the room conditions were out of the temperature or relative humidity control band, provided we could mount extremely flexible contacts in such positions as to contact small wires near the ends of the pen arms on the instrument. It was clear that extremely light pressures must be used if the contacts were not to impede the recording pens. These light pressures would require low voltages and low currents if the contact resistance was not to have too great an effect on the system.

The two-pen arms of the Friez unit were fitted with light-weight contacts and lead wires were brought out at the axis of rotation of the pen arms in order to minimize the force. Four flexible contact wires were then mounted on a vertical post which is normally used to move the pen arms away from the chart. These contact wires were



connected to a common lead and the lead wire was connected to a suitable relay circuit as shown in the wiring diagram.

The contact wires were made of No. 28 Chromel thermocouple wire, about 0.013 in. in diameter. Each of the wires was formed into a helix with a mean diameter of 0.3 in. and having four turns. The wire at one end of the helix was fastened to the support, the other end was looped out 1.5 in. and bent back to the contact point on the pen arms. This loop plus the helix resulted in a very flexible contact thus causing a negligible error in the pen arm position during the time when the pen arms were indicating out of the control band. Normally the contact wires have no effect on the pen arms since they are not in contact when the system is in control.

A Struthers-Dunn sensitive relay, No. 112XAX, having a 2.0-volt d-c. 6.25-ma. coil was connected to a 1.6-volt d-c. voltage output from a Schauer Electrox copper oxide instrument rectifier Type B4. The rectifier was coupled to a 110-v. 60-cycle supply by means of a Thordarson 110-v. to 2.5-v. filament transformer. The relay was shunted with an 8.0-microfarad dry electrolytic capacitor which served to filter the rectified voltage. The control relay in turn actuated an HB Instrument Co. mercury plunger relay which caused the signal horn to sound. The switch between the horn and the point B on the circuit diagram was used to disconnect the signal horn but permitted a red signal light to remain on as long as the conditions were out of control.

This simple addition to our existing Friez instrument resulted in a substantial saving in maintenance time and expense. We have never had any signals result from malfunctioning of the signal system as occurred with the system described earlier. The useful function of the recorder-controller has been completely replaced by this system and results in a saving of approximately two hundred dollars in instrumentation.

Automatic-reset Device Added

Another feature which we were able to incorporate in this system, which resulted in a further saving in time and expense, was an automatic-reset device. Before installing this feature it was necessary to have an attendant stay at the laboratory or return to it in order to turn on the switch between the signal horn and point B in the circuit diagram, after the room had again returned to the proper conditions.

Referring to the diagram, it was necessary to connect the circuit (enclosed in dotted lines) at points A, B, and C, and to remove the wire between points A and B. The switch between the signal horn and point B is not used except when it is desired to have the signal horn turned off for adjusting the control band width. It is only necessary for the attendant to use the push button to disconnect the horn from the circuit. The normally-open relay then holds the normally-closed mercury plunger relay open until the contacts break on the Friez instrument. When the Friez instrument contacts break, the normally-open mercury plunger relay opens, thus de-energizing the automatic reset relays.

The two relays used in the automatic-reset circuit could of course be replaced by a single relay with suitable contacts and power-carrying capacity.

The writer wishes to acknowledge the assistance of Mr. Robert E. Duff, Jr., who assembled the necessary apparatus for converting the Friez instrument and drew the circuit diagram. The writer also wishes to acknowledge the assistance of Professor Howard C. Roberts who gave several helpful suggestions on the organization of this article.

The devices discussed are located in the Plastics Laboratory at the Univsity of Illinois. This laboratory is under the direction of Professor W. N. Findley who encouraged the development of the above-described apparatus.

THE MASS SPECTROMETER
Its Accomplishments, Applications *and* Future

By KENNETH E. BURMASTER, Ass't Dep't Supervisor, Mass Spectrometer Section, Laboratory Division, and ERNEST C. EVANS, Development Engineer, Mass Spectrometer Section, Laboratory Division, Carbide and Carbon Chemicals Corp., Oak Ridge, Tennessee.

NUMEROUS inventions have done and are doing a great service to mankind; yet few people know of them. Those with which we come into contact every day, such as the electric lamp and the radio, are well-known to all. Others, by the nature of their service, are confined to certain groups of people. The electric generator is well-known by those people in the electrical field; the radio transmitter by the radio engineers. But even with these, the public knows of their existence and generally what service they render. The mass spectrometer, on the other hand, is not well-known within the technical groups with which it is associated; and to the general public its services and even its name are practically unknown. One reason is the relatively small number of mass spectrometers; another reason is that the accomplishments of the mass spectrometer, though of great value to mankind, have not been glamorized by the newspapers.

Mass spectrometry has not only played an important part in advancing science frontiers but also in shaping the technological progress of the world. While much fundamental scientific knowledge has been uncovered by the mass spectrometer, this instrument has been indispensible also in many fields of applied science. Its applications have varied from serving as a "drunkometer" to producing atomic bombs. But what is this electromechanical robot; what does it do, and how does it do it?[1] To answer this question let us start with its origin.

If one searches back into the scientific journals he will find several articles about F. W. Aston who is credited with making the first mass spectrograph: in 1912 at the Cavendish Laboratory in England.[2] The mass spectrometer is a modification of Aston's mass spectrograph in which the answer is read from an electrical instrument instead of a film and, because it gives more accurate answers, it is in more general use today. It is only fair to say, however, that Thompson made a positive ray apparatus in 1907 which contained many of the essentials of the mass spectrograph and led the way to its development.[3] Since the mass spectrometer is the latest and most widely used development of the two instruments, a description of its operation will be given.

Although the mass spectrometer is capable of accomplishing many amazing feats, the theory of its operation is quite simple. The "senses" of the mass spectrometer are located in the analyzer tube which, with its associated electronic units and vacuum pumps, analyzes the sample. Referring to Fig. 1, the operation of the instrument commences with the admission of a sample into the source. The source is contained in one end of a bent tube (the analyzer tube) inside of which a high vacuum is maintained. In the source the sample is ionized: it is broken up into charged particles which are representative of the original sample. This is usually accomplished by bombardment with electrons supplied from a hot filament. These charged particles, or ions, are

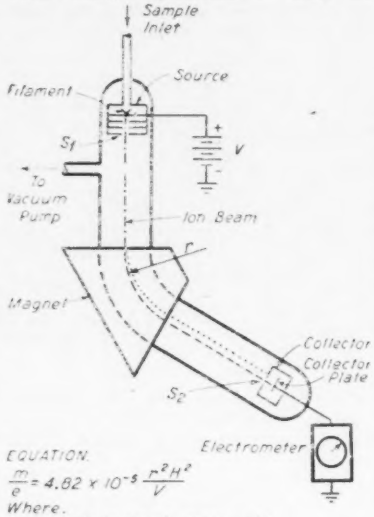


Fig. 1. Nier type mass spectrometer.

subjected to an electric field which accelerates them towards the bend in the tube. At the start of their journey the ions are made to pass through a system of narrow slits, and emerge through slit S_1, which collimates them into a thin beam or ribbon. This beam of ions passes down the tube until it reaches the portion crossed by the magnetic field. This field causes the ion beam to bend. As it bends, it fans out: the light ions are deflected considerably; while the heavy ions are deflected very little. Fig. 1 shows the heavy ions as dashes and the lighter ions as dots. This deflection effectively separates the ion beam into a fan or spectrum of the various masses present, much as sunlight is separated into its various colors by a glass prism. By varying either the accelerating potential or the magnetic field strength, ions of any mass may be made to pass through slit S_2 and to strike the collector plate located at the opposite end of the analyzer tube. The equation for the analyzer tube illustrated is given in Fig. 1. The quantity of ions impinging on the collector can then be measured by means of an electrometer, which is an extremely sensitive electric-current-measuring instrument. A proper mathematical treatment of the data obtained will reveal both the chemical composition of the sample and the relative amounts of each component.

In accomplishing its qualitative analysis the mass spectrometer actually measures the mass to charge ratio (m/e in the equation of Fig. 1) of the characteristic ions formed from the various constituents of a sample. Since the charges on the ions are usually one unit charge, relative mass may be determined directly, but sometimes the charge equals a small whole number times unit charge, which may cause some difficulty. For example, a particle of two charges may strike the collector with one of unit charge and half the mass. Special operational techniques have been developed to cope with this situation. The mass spectrometer is, in fact, the most accurate means of obtaining relative mass measurements—which may be determined to within one part in 100,000.[4] It measures the mass of a particle as related to the mass of another particle, usually as referred to oxygen as 16 mass units in the chemists' table. Some of the better instruments can resolve ions having a difference in mass of only one part in 30,000.[5] Its unique abilities and high degree of accuracy have made it very valuable to the research scientist.

The mass spectrometer has made many outstanding contributions to the field of science. The initial work accomplished by the first mass spectrograph was done by Aston on neon gas.[6] This gave the first satisfactory evidence that neon consisted of isotopes, the mass of each being a whole number, and it was definite proof of the existence of isotopes. As later work was done on other elements it soon became evident that the masses of all atoms, to a close approximation, were whole numbers (multiple of some unit). This explained why, in Mendeleff's periodic table of elements, the atomic weights of the elements were near to, but not all multiples of some unit—some common building block.[7] The reason became obvious: that many of the elements were actually a mixture of isotopes of different mass. Through continued use of the mass spectrometer by such men as Aston, Bainbridge, and Dempster, accurate measurements of the relative mass of the majority of the elements and their isotopes were made and tabulated. Bainbridge accurately established the comparison of the masses of light par-

*Approval for release authorized by the U. S. Atomic Energy Commission.

ticles found in nuclear disintegration and from this obtained experimental proof of Einstein's theory of the relation between mass and energy.[8] The velocity of a variety of both positively and negatively charged particles was studied under many conditions, and the ratio of the charge to the mass was accurately determined. Since the mass spectrometer could separate the isotopes of an element (an impossible fact to accomplish by chemical means and a very difficult one to do by physical methods) it was used to produce isotopes for purposes of basic research. The first uranium 235, an isotope of uranium 238, was separated by this means by A. O. Nier in 1941.[9]

Another outstanding scientific accomplishment of the mass spectrometer is its ability to take apart complex organic molecules and reveal their internal

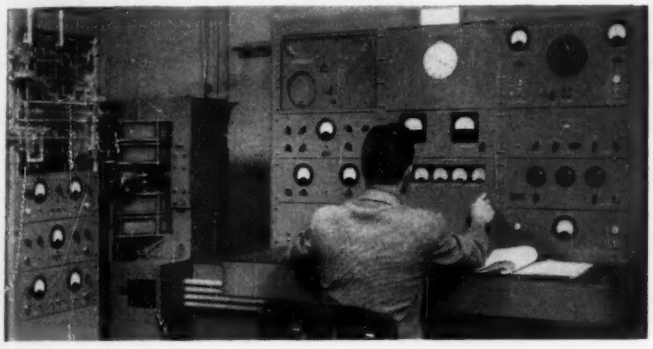


Fig. 2. A modern mass spectrometer (Courtesy Consolidated Engineering Corp.).

structure. Many organic compounds have molecules consisting of the same number and kinds of atoms, but these atoms are bound together in many different patterns, each one producing an organic compound with different characteristics. These complex molecules break up into representative ions when bombarded by electrons; and, when they are analyzed by the mass spectrometer, they reveal the structure of the organic molecule. Isomers may be analyzed with little difficulty. Fig. 3 illustrates the possible dissociation of the butane molecule and the isobutane molecule due to the electron bombardment. Normal butane will break up into more ions of mass 29 than isobutane since the fracture of one of its carbon bonds can produce two ions of mass 29, while it would require the fracture of two carbon bonds to obtain one ion of mass 29 from isobutane. Similarly, there are three points in the isobutane molecule where a single carbon bond may be broken and an ion of mass 43 formed. In the normal butane molecule there exist only two such points. It is a quick, easy method of accomplishing a task which would be a long difficult one to do by other means. Medical research has been greatly advanced by the mass spectrometer. Rapid and accurate analysis of the components of a patient's breath are possible, thereby giving an instantaneous picture of his metabolism under different degrees of exertion. In another test the patient may be given food containing an abnormal ratio of isotopes. By later removing small pieces of tissue, bone, or blood from the patient and analyzing these spectrometrically, the presence of the food in each can be determined. In the field of biology, Pollard and Davidson mention the following experiment:

> Thus if carbon dioxide containing 10 percent C_{13} [Carbon 13], in place of the usual 1 percent, is given a plant to breathe, any part of the plant which subsequently shows that the proportion of C_{13} is abnormally high must have received that C_{13} from the labeled carbon dioxide. A sample of material which has an abnormal ratio of isotopes though it is chemically identical with ordinary material, is nevertheless detectable by the mass spectrometer.[10]

The commercial applications of the mass spectrometer are as numerous as they are varied. It is rapidly becoming an integral part of all large industrial laboratories where it is utilized for both research work on improving processes or developing new products, and also for inspecting the finished products. For an example of what it means to a modern petroleum industry's laboratory, Deegan says the following about what the mass spectrometer does:

1. Solves problems that can't be solved by any other method, or
2. Solves problems so much quicker than any other method, that it saves enough time to pay for itself, or
3. Although there are other methods to solve some of our problems, they take too long to be of any use in checking operating processes.

He further states:

> One of the things that makes it particularly useful to the petroleum industry is the fact that such closely related hydrocarbons as normal butane, isobutane, and butene, or normal pentane and isopentane, can be distinguished from each other, and each one measured separately just as easily as any other molecules.[11]

Many other industries such as the gas, chemical, and rubber industries, rely a great deal upon gas analysis. The mass spectrometer is especially suited to the analysis of gases and complex mixtures of gases. Old methods of chemical analysis still being used in most laboratories have serious limitations, although they do give valuable information. The mass spectrometer can resolve a complex gas mixture in one operation and within a few minutes. The analysis is fast and there is no hold-up time.[12]

The increased use of the mass spectrometer in industry is bringing forth many new developments and these are helping to widen the field of applications of this instrument. Recent improvements have made it possible to perform quantitative analyses of mixtures of chemical solvents, organic intermediates, and derivatives with the mass spectrometer.[19,20] In the past, the poor performance of the mass spectrometer with samples containing water or alcohols limited its use in the solvents industry. With this new ability to analyze both water and alcohols, the usefulness of the mass spectrometer to the chemicals industry has increased tremendously. Now, practically any material which has sufficient vapor pressure to be admitted into the sampling system can be analyzed. Even samples containing as much as 99.9 percent water can be run. The increased sensitivity of commercial mass spectrometers is making them especially suited for purity studies as they are now able to measure even trace quantities of impurities in a sample. The use of this powerful analytical tool is rapidly increasing in the new synthetic fuels industry where the analysis of the many oxygenated materials making up the by-products is of paramount importance.[21] A few months ago 8000 analyses of light hydrocarbons were performed by about seventy laboratories. Such instruments as infrared and ultraviolet spectrophotometers and the mass spectrometer were used in addition to low-temperature distillation and various chemical processes. In reviewing the tests Starr and Lane wrote:[22]

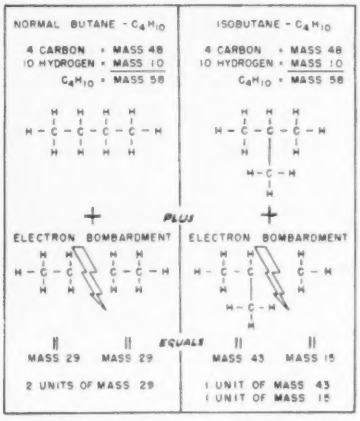


Fig. 3. Possible dissociation of the butanes by electron bombardment.

> The mass spectrometer method appears to be best for the determination of individual paraffin hydrocarbons, total butenes, and butadiene in high concentrations.

An extremely efficient method of locating minute leaks in vacuum systems

has been developed by utilizing the mass spectrometer. This is accomplished by spraying a gas (usually helium) over the outside surface of the vacuum system and continuously sampling the gas from inside the system with a mass spectrometer. When the spectrometer shows the presence of the gas which was sprayed upon the outside, it indicates that this gas has entered a hole in the vacuum system. By localizing the gas spray to a small area, the exact location of the leak may be determined. Leaks so small as to admit only 10^{-9} standard cubic centimeters of helium per second are detectable.

Recent developments[18] in the leak-testing method have made the leak detector applicable to the testing of pressure systems. In this case the system is filled to a positive pressure with helium (or a mixture of helium and another gas). A probe consisting of a small suction nozzle is attached to a rubber hose, the other end of which is connected to the leak detector-sampling line. This probe is passed over the outer surface of the pressure system, and any helium leaking out will be sucked into the probe and indicated by the leak detector. A careful probing of the surface will pin-point the location of the leak. This method has been used to test buried natural gas lines for leaks. Leak testing is important in the fabrication of high-vacuum equipment, cyclotrons, refrigeration units, supersonic wind tunnels; in the manufacture of radio tubes, transformers, rectifiers; and in the construction of large industrial plant equipment which is to operate under vacuum. In fact it is essential in the manufacturer of the mass spectrometer itself. This phase of mass spectrometry is becoming so important that several large companies are now manufacturing leak-testing equipment in quantity.[13]

Owing to the loss of time and the expense of taking samples of plant processes and transporting them to a laboratory, many laboratory instruments have been moved into the plant. In many processes the time required for an analysis is of great importance since any change occurring in the plant's operation should be known immediately by the operating personnel. This enables them to apply corrective measures before the malfunction has gone far enough to destroy the product or, in some cases, the production equipment. The mass spectrometer is especially suited for such work since it accomplishes its analysis rapidly and, in addition, may be used for either a batch method of analysis or for a continuous analysis. In the latter case, a recorder has been used to continually print both the qualitative and quantitative analyses simultaneously as they are reported by the spectrometer. In fact, a step further may be taken and the signals given by the mass spectrometer may be employed to automatically control the process. The instrument is then quite applicable to the design of the automatic factory and is not unlike an automaton. In connection with this automatic feature, the mass spectrometer may be used to give warning of a dangerous condition existing in a plant. Such a condition might arise in the plant processing of explosive chemicals or in the liberation of poisonous gas into sections where workers are present.

The versatility of the mass spectrometer is evidenced by the fact that it has been used as a "drunkometer" to analyze the alcohol content of the breath from suspected drunks, and as a "calutron" to make atomic bombs.* It helped usher in the Atomic Age: The discovery of the material used in the first atomic bomb, the production of the first minute quantity of the material, the later large-scale production and

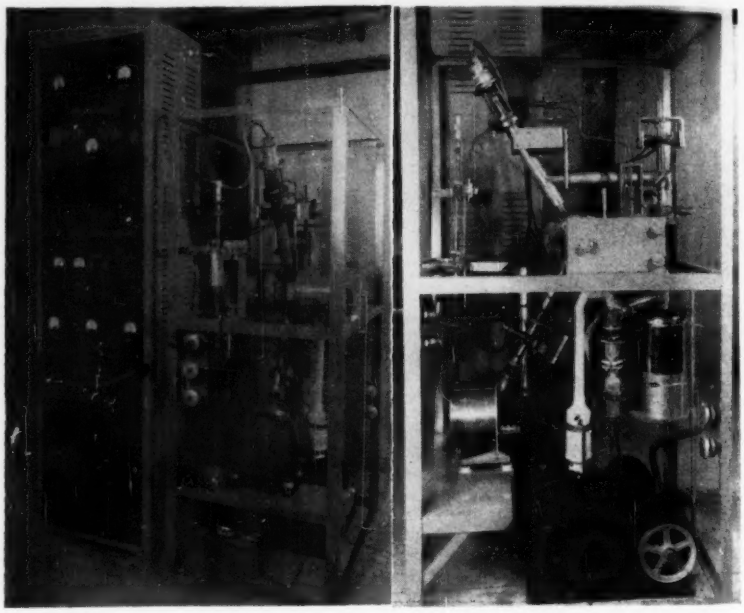


Fig. 4 (left). Nier type mass spectrometer: electronic equipment, analyzer tube, and vacuum system. Fig. 5 (right). Bent analyzer tube and vacuum system. (From Alfred O. Nier, reference 29.)

analysis of it, were all done either entirely or in part by the mass spectrometer. Dempster, using a mass spectrometer, discovered uranium 235, an isotope of uranium 238, and reported it in 1935.[14] Nier separated samples of uranium 235 in his spectrometer and supplied them to the atomic energy project for the early experiments on bomb materials.[15] As the work progressed, the mass spectrometer was indispensible in the analysis of the uranium-separation processes. The first plant to produce uranium 235 was the electromagnetic plant which utilized immense mass spectrometers or "calutrons" to separate it from uranium 238.[16] A mixture of the two uranium isotopes was fed into the source of the huge instrument and the adjustments made so that uranium 235 accumulated on the collector plate.

Since these large spectrometers operated under vacuum, as did also the mammoth gaseous diffusion plant constructed later, leak testing was of utmost importance both in the construction and during the operation of both plants. Here, again, the mass spectrometer could fill the need. Then, in the process of separating uranium 235 from uranium 238, there was always the question of how well the plant processes were accomplishing their work. An analysis of the quantity of isotopes present at each stage of the process would be of great value. But what fast accurate means of analyzing isotopic abundance could be found—the mass spectrometer, of course. In writing about the atomic energy project, Smyth makes the following statement:[17]

> Among the various instruments designed or adopted for project use, the mass spectrograph [spectrometer] deserves special mention. The project was fortunate in having the assistance of A. O. Nier—whose mass spectrograph methods of isotope analysis were sufficiently advanced to become of great value to the project, as in analyzing samples of enriched uranium [higher 235/238 ratio than in natural ore]. Mass spectrographs were also used in pretesting parts for vacuum leaks and for detecting impurities in the process gas in the plant.

It is evident that in the production of the first atomic bomb, the mass spectrometer not only aided in the construction of the plants and produced material for the bombs, but analyzed the product and watched over the process. To say that it was indispensible in producing the first atomic bomb and to the development of atomic energy is to put it very lightly.

*"Calutron" is a contraction of "CALifornia University cycloTRON."—EDITOR.

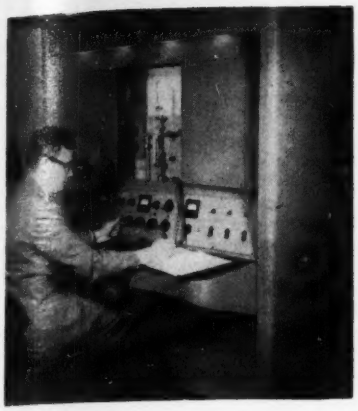


Fig. 6. **A modern mass-spectrometer-type leak detector being used for leak testing. The operator is spraying helium gas on the test object and watching for an indication of a leak. (Courtesy Consolidated Engineering Corp.).**

While the mass spectrometer has already performed a sufficient number of outstanding accomplishments to earn a prominent place in history, it has done this in its youth; it is now just reaching maturity and is prepared to attain new heights. The future holds innumerable opportunities for the mass spectrometer. Now that it is being manufactured on a production basis, its numbers will multiply rapidly and it will find many fields anxiously awaiting its services. In scientific research the mass spectrometer will aid in the search for new elements and new isotopes. It will give invaluable aid in determining the physical constants of these as they are found in nature or produced in nuclear piles. It will analyze new compounds to be created by the chemist and aid him in developing and studying new processes. Commercial laboratories will do away with antiquated methods of analysis and adopt the efficient and versatile mass spectrometer for a large part of their work. It will enable the plant engineer to "see" through steel reactors so that he may know how far a reaction has gone at any moment. In many automatic plants it will keep a continuous vigil over the production process and will dictate messages to control mechanisms to maintain the correct operation of the plant.

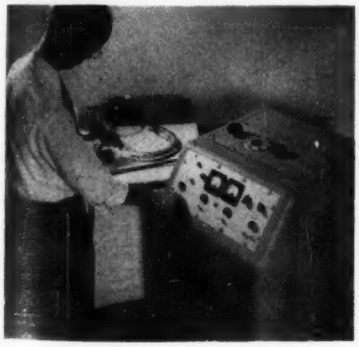


Fig. 7. **An isotope-ratio mass spectrometer (Courtesy Consolidated Engineering Corp.).**

Thanks to the mass spectrometer, a new and powerful tool will be furnished in quantity to the medical and biological research men. Named "tracer technique," it will utilize both radioisotopes and stable isotopes now being manufactured in atomic piles, cyclotrons and other "atom smashers." The medical doctor will be able to search for the causes and cures of diseases such as cancer and heart disease. Using "tracer technique" the biologist will find the answer to many questions about living organisms, vitamins, better food for man, and better fertilization methods for plants. Perhaps photosynthesis, the important process by which plants take air and water and with the aid of sunlight convert them into food for man, will be fully understood and duplicated by man. In all of these investigations the mass spectrometer will play a leading role.

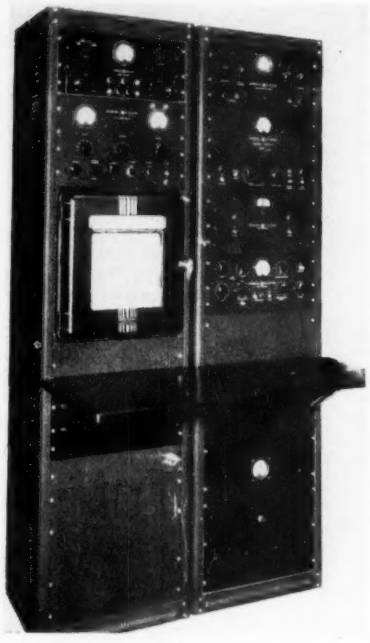


Fig. 8. **High-resolving-power mass spectrometer (Courtesy General Electric Co.).**

By all these services which will be rendered by the mass spectrometer, great gains in scientific and technological knowledge will be made. When these advancements are applied to the production of improved new items such as medicines, foods, plastics and fuel, mankind will have a higher standard of living. When the automatic plant is perfected, and with the replacement of old methods of analysis, much human drudgery will be eliminated. Furthermore, while such inventions as the automobile have brought many gains to man, they have also introduced great social problems. Where is the fact more evident than in the daily report of death caused by automobile accidents? The mass spectrometer, however, brings forth to mankind its gains free of hazards. It would only be in man's misuse of the gains given him that harm would result.

In view of all its accomplishments, its applications, and its future, the mass spectrometer is certainly worthy of world recognition.

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Temperature Measurement *and* Control *in the* PROCESS INDUSTRIES*

By DAVID H. FULLER, Mgr. Electronic Products, The Foxboro Co., Foxboro, Mass.

Introduction

ALTHOUGH the science of measuring and controlling temperature is old, the advance in recent years tends to invalidate the criteria for the correct method to use which were in effect only a few years ago. Modern processes make much greater demands upon temperature measuring and controlling instruments. Modern instruments have advanced so rapidly that in many instances several different methods would seem to be equally applicable. The instrument engineer and the process designer are thus faced with more complexity, both on the demand and supply side of the picture.

On the other hand, the greater demands for accuracy, distance, sensitivity, stability, etc, made by modern processes have, in most instances, been more than met by modern instruments. It would appear worthwhile to take stock and review the situation quite broadly at this time.

General Outline and Limitations

Most of the advance in temperature measurement has been based upon primary elements and principles long known to industry. The advance has been in details and in the application of methods of using these primary elements and principles in general. There are, of course, notable exceptions which we will cover briefly.

In a general review, it is perhaps wise to restate the basic fact that temperature is merely a measure of the level of heat energy in a body. It is virtually always necessary to measure temperature by observing some other effect and interpreting it in terms of a temperature scale. One of the earliest forms of temperature measurement involves the expansion of a liquid or gas when it is heated. The International Temperature Scale is based upon the energy level at which certain changes of state, such as the triple point of oxygen, the freezing of water, the freezing of gold, etc., occur. Interpolation between these points has until recently been based upon the expansion of gas. At the present time, however, the scale is interpolated between these points by reference to the change in electrical resistance of a highly refined and standardized platinum wire resistance bulb due to a change in temperature. At higher points, interpolation is made through observation of radiant energy phenomena and by thermoelectric means.

The actual determination of the International Temperature Scale is mainly of concern to more theoretical scientists than we here represent. However, the effects of this work become more and more important as higher and higher absolute accuracies are required for what might be termed "interchangeability of process applications."

Current examples of instruments operating on the expansion of a liquid or gas are the so-called glass stem thermometers, used everywhere from household use to the most exacting laboratory use. In general, however, glass stem thermometers are usable only for indicating readings, although in some instances contacts may be sealed into the glass to provide a degree of alarm or control. Further discussion of this particular type isn't necessary here.

Of more specific interest are those instruments in which the liquid or gas is enclosed in a bulb, usually metallic, and in a capillary tube extending to a Bourbon type pressure spring. These filled-system type instruments offer the advantage of distance between the point of measurement and the point of reading, and of course, offer such functions as control and recording.

The expansion of a solid may also be used to measure temperature, and this principle finds use in bimetallic thermometers used for indication or, in some instances, for non-indicating control, as in the common thermostat. However, except as an indicator, this type does not generally enter largely into process work.

The mention of the International Temperature Scale introduced another form of measurement based upon the electrical resistance of a conductor. Most materials change their electrical resistance with temperature. In only a few materials, however, is this change predictable enough to permit its being used as a measure of temperature. Platinum, nickel, copper and similar metals are long established in this field. Carbon is a relatively recent entrant and still more so are the large variety of metallic compounds which are normally considered as insulators, but which do conduct electricity and have, in many instances, rather startling changes in resistance with temperature. These compounds when used as temperature sensitive elements are generally known as Thermistors. In all of these resistive elements, it is, of course, necessary to have some sort of instrument to measure the resistance and interpret it in terms of temperature. These instruments can range from very simple direct deflection types to relatively complex mechanical and electronic instruments. In the direct deflection type, control and recording functions are inherently difficult because of the low power available, but on the other hand, some of the least expensive controllers are based on direct deflection instruments. The mechanical and electronic types are generally characterized by the large power they make available and hence their flexibility in application to recording and control functions.

The last method of general importance is based upon the principle that dissimilar metals when joined together at two different points develop a voltage when the two junctions are at different temperatures. The combination is, of course, known as a thermocouple and dissimilar metals such as iron and constantan, copper and constantan, platinum and platinum-rhodium alloy, and various others are employed. Here again, some type of direct deflection or mechanical or electronic instrument must be used to measure the small voltages set up and interpret them in terms of temperature. In general, these instruments are of the same type as used for resistance measurements.

In the higher temperature field, either resistance elements or thermocouple elements may be heated indirectly by radiation. The readings taken from the resistance instrument or thermocouple can then be interpreted in terms of the temperature of the radiating body. However, it must be noted that while the technique employed is different, the actual principles can be classed under resistance or thermal electric principles.

The last general type of temperature measurement is based upon the comparison of the color of a radiating body of unknown temperature with the color of another radiating body, the temperature of which can be controlled. By inference, the known temperature of the controlled body is then equal to the unknown temperature. Optical Pyrometers using this principle have long been straight indicating instruments, though recently the use of photocells has permitted automatic operation of optical Pyrometers and recording and control functions from this source.

There are, of course, infinite varieties of applications of these principles. However, in general the variety is one of detail rather than one of basic principle.

It will be noted that we have refrained from classifying the use of above principles in terms of the range of temperature to be covered. The reasons for this omission will appear further, but in general, it can be stated that it is no

*Presented at Short Course on "Instrumentation for the Process Industries," Agricultural and Mechanical College of Texas, October 12-14, 1949.

longer possible to arbitrarily classify different principles of measurement according to temperature range. There are too many overlaps and too many other features entering into the use of these principles.

Definition of Terms

Probably there is no greater cause of waste of money in instrumentation than the efforts of manufacturers to meet and users to maintain standards of "accuracy" which, in some instances, are unnecessary. In many instances, a simple understanding of the reasons for "accuracy" will point out great savings in such efforts. A number of organizations are working for the clarification of terms and clearer understanding of their meanings, but the work still has a long way to go.

The chart shown in Fig. 1 is an effort to show the relation of various terms used in discussion of instruments. Note that the chart is divided into two sections, one covering the over-all system, and one of particular interest when the sensitive element itself can be isolated from the system as is the case in electrical instruments.

In considering the over-all system, note that there are two major terms: "sensitivity" and "accuracy." Let us start out by defining *accuracy* as a statement of the deviations between the readings obtained from an instrument and a known temperature, as determined by accepted standards. *Sensitivity* may be defined as a statement of the change of temperature required to cause the instrument to move toward the new temperature.

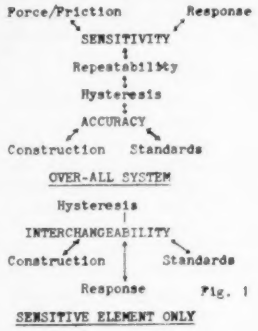


Fig. 1

In installations whose primary purpose is to control, sensitivity is usually more important than accuracy. In most instances, it is more important to hold the temperature of the process at a given temperature point than it is to know exactly what that actual temperature is. In general, the only reason for controlling the temperature is to obtain a desired product. The actual temperature *reading* at which it is necessary to set an instrument to obtain the desired product is usually unimportant if the *same* reading always produces the same product (repeatability).

A major exception to this general statement is in those cases where it is desired to duplicate several installations, in which case it would be inconvenient to have to set different instruments at different readings to obtain the same product. Another exception is where it is necessary to correlate installations and to predict the temperatures which will have to be maintained in different portions of the process to obtain a desired end product.

Need for the absolute temperatures in this case is usually confined to pilot plant or laboratory practice and in such specialized applications as accounting based upon the temperature or temperature difference of flowing fluids.

In control, in general, the sooner the instrument finds out about a change in temperature, the better chance it has of correcting for the change and keeping the process under control. Obviously, the higher the sensitivity of the system, the smaller the degree of temperature change necessary to operate the controller and the better the control that will be obtained.

As shown in Fig. 1, sensitivity is affected by the force/friction ratio, the response and the repeatability (or dead space) of an instrument. Response may be defined as a statement of the time required for instrument to reach a new value after an actual change of temperature. Response and sensitivity are often used as synonyms, but there is every advantage to retaining the distinction. Response is affected by the type of instrument used and by its installation. Speaking strictly from the instrument standpoint, the "instrument response" should not be confused with "process lags" which can be defined as the time interval between cause and effect in the process. In other words, the time interval between the cause, which changes the temperature, and the effect, or change of temperatures reaching the sensitive element of the instrument.

The sensitivity of an instrument is directly affected by the force/friction ratio inherent in its construction. The greater the friction in the instrument, the greater the power required to overcome this friction and start the instrument moving. This power, in general, is derived from the change in temperature. Lower power instruments such as direct deflection electrical instruments and filled system instruments must be designed with a minimum of friction to retain sensitivity. A major advantage in electrical and electronic instruments is the availability of a great deal more power for a given change of temperature, and hence the possibility of heavier construction, which, in general, implies greater friction.

The remaining factor in sensitivity is repeatability, the degree to which an instrument gives the same reading for a given actual temperature. Dead space caused by lost motion and friction reduces sensitivity and controllability and in addition makes it difficult to make corrections in operation.

Repeatability should not be confused with hysteresis which normally has no effect on sensitivity or controllability. In general, all changes in nature exhibit a property known as hysteresis. Thus, any element which is subjected to a change, and then subjected to another equal change, in the opposite direction, will not come back to its original condition exactly. The difference between its original condition and its final condition may be stated as its hysteresis. Tieing this down to an instrument, if a pressure spring is deformed by a change in pressure and then allowed to go back to the original pressure, it will take a permanent set and will not return to its original position, even though there is no friction present. This hysteresis of pressure springs specifically may vary from being negligible to being a major factor in the over-all accuracy of an instrument. Since hysteresis is proportional to the excursion of the pen it normally does not affect control since the excursions are small and hence the lack of repeatability due to hysteresis is also small. It is important not to confuse hysteresis with dead space.

In applying the above definition of accuracy—a statement of the deviations of instrument readings from known standards—it is necessary that we simplify the problem by eliminating response by allowing the instrument to come completely to rest. Under these conditions, the accuracy of the instrument cannot be greater than its responsibility plus its hysteresis.

An accuracy statement is directly affected by the standards used to define it. There is, of course, no absolute standard. The International Temperature Scale is the nearest approach. A standard may be defined as a method of measurement in which the errors due to sensitivity, hysteresis, response, etc., are better known than the same errors in the instrument being tested and hence may be allowed for. Obviously, the better the standard, the better the statement of accuracy.

All instruments undergo a change in accuracy with age. The type of construction used in the instrument determines whether this change will be large or small. The use of terms such as "calibrated accuracy," "factory accuracy," etc., represents an effort on the part of the manufacturer to avoid making statements based on conditions beyond his control. Terms such as "sustained accuracy" or just plain "accuracy" must take into account the probable conditions of use—and abuse—of the instrument. On the other hand,

Continued on page 290

INSTRUMENTS ON THE MARCH

Wear Test *for* Automotive Gear Lubricants

WASHINGTON, D. C.—Recent investigations at the National Bureau of Standards by S. A. McKee, J. F. Swindells, H. S. White, and Wayne Mountjoy have shown that the SAE extreme-pressure lubricants testing machine can be adapted to measure accurately the wear obtained with various automotive gear lubricants under simulated service conditions. This apparatus was originally designed for testing load-carrying capacity of gear lubricants under *fixed high-speed and shock-loading;* but it provides a sensitive means for the evaluation of lubricants with respect to wear at *high-torque and low-speed operation.* The new test therefore makes it possible to detect any significant difference in the performance of lubricants meeting the requirements of the same specifications.

Of the various laboratory testing machines commonly used in the study of automotive gear lubricants, the SAE machine more nearly simulates gear operation. Two contacting cylindrical test cups of this machine are rotated at different speeds under load, providing a combined rubbing and rolling action that is typical of loaded gear teeth. A further similarity is a constantly-changing line contact with respect to the surfaces of both cups, hence no one point on the periphery is under continuous stress.

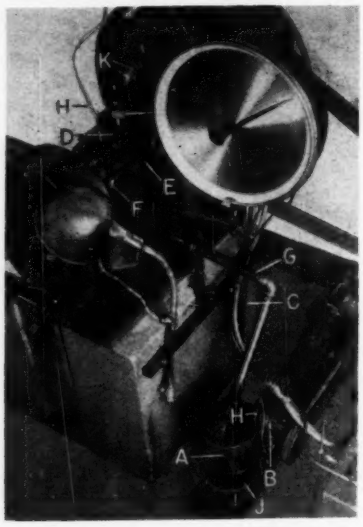
The machine is particularly adaptable for wear tests because the test specimens are of such size and shape that accurate indications of wear may be obtained by determination of loss in weight. Also, any wear that occurs on the test cups does not materially affect the area of contact under a given load. On the other hand, the method of lubricating the test surfaces is not especially suitable for long-time tests; and so it was necessary to modify the machine in this respect.

Although the primary objective in modifying the lubrication system was long-time operation, it was decided also to provide better temperature control of the upper test cup. In the original machine, the lower test cup is supported half-immersed in a small oil box. Lubrication between the two cups is effected by the oil carried up as the lower cup rotates. Since only the lower cup is cooled by immersion in the oil bath, the upper cup runs at a considerably higher temperature. For this reason, an additional oil reservoir of larger capacity and a circulating system were provided for applying a stream of oil to the upper test cup.

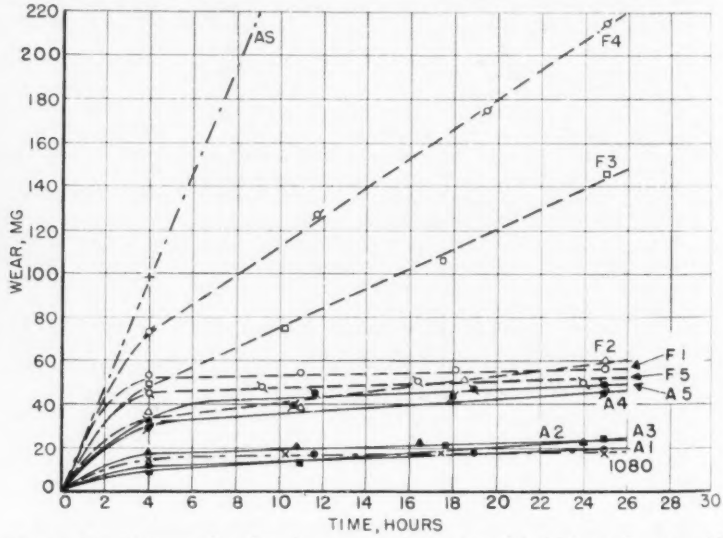
In the modified lubrication system the oil being tested is drawn from a reservoir by a motor-driven pump and delivered through a quarter-inch pipe to the top of the upper test cup, which is covered by a special oil splash guard. The oil then drains to the oil box, which is fitted with two quarter-inch overflow pipes so located that the oil level in the box partially immerses the lower test cup. The oil from the overflow falls into open fittings in the three-quarter inch drain pipe and returns to the reservoir. Heat is applied to the oil reservoir and delivery pipe. Thermocouples in the oil box and oil reservoir provide a means for temperature measurement and control. Counterbalanced overflow pipes, splash guards, and an oil thrower prevent excessive oil leakage around the test cups and oil box.

The lubricants used in the Bureau's investigations were SAE 90 grade and included a Navy contract 1080 mineral oil, five lubricants conforming to U. S. Army Specification 2-105B, five lubricants conforming to Federal Specification VV-L-761, and one lead-soap active-sulphur lubricant.

In these wear tests, the upper cup is driven at a speed of 500 rpm. with a 3.4-to-1 gear ratio between the upper and lower cups, thus providing a 2.4-to-1 ratio of rubbing to rolling at the contacting surfaces. The specimens, steel Timken test cups (T-48651), have an average (rms.) surface roughness of 25 to 30 microinches as measured with the Profilometer. Each lubricant sample (two quarts) is circulated at a rate of about 500 grams per minute. With a constant oil temperature of 225 F., tests were made at constant loads of 90, 135, 180, and 225 pounds (scale readings). Tests were also made at 250 F. and 180-lb. load. These conditions approximate the range of con-



The SAE Extreme-Pressure Lubricants Testing Machine, as modified by the NBS for wear test with automotive gear lubricants. Lubricants are rated by the load (scale reading) when scuffing occurs during a load-carrying capacity test and by the wear per hour after wearing-in on the wear tests. By means of a special oil-circulating system, oil from reservoir A is drawn through pipe C to upper test cup which is covered by splash guard D. The oil then drains to box E, hence through overflow pipes F into the drain pipe G and back to the reservoir. Heaters are located at J and K and thermocouples at H.



Wear (milligram) versus time (hours) curves for all lubricants (SAE90) operating at 135-lb. load and 225 F. These data indicate a run-in period of about four hours, after which wear continues at a constant rate. With this intermediate load, only three of the lubricants show appreciable wear after the run-in period. Lead-soap active-sulphur lubricants, AS; Army specification (2-105B) lubricants, AS; Federal specification (VV-L-761) lubricants, F; Mineral oil, 1080.

ditions covered in the usual high-torque low-speed gear tests.

The test cups were weighed before and after each period of operation, the loss in weight being used as a measure of wear during the test period.

In general, the data obtained in these tests indicate that there is a run-in period of high rate of wear for a few hours, after which the wear settles down to a fairly constant rate. In a graphic plot of such data the straight portion of the curve usually is well established by 25 hours of operation. The slope of this portion of the curve is more significant from the standpoint of estimating gear life than the observed loss in weight for any given length of time. At the higher loads the rate of wear with some of the lubricants tested showed a marked increase, whereas with others there was little effect.

In most of the tests, Profilometer readings of the surface roughness of the test cups were obtained at intervals during the test run. For those tests where the rate of wear was relatively low, the roughness decreased in the run-in period and tended to level off in a range between 10 and 20 microinches. As the rate of wear increased, there was a trend for the roughness to increase. This was especially noticeable in cases of excessive wear where there was definite "ridging" of the cups, which in some cases was beyond the range of the Profilometer.

In connection with a brief study of the effect of the original surface roughness of the cups on the rate of wear, test data were obtained with the mineral oil and one of the Army specification lubricants operating at 225 F. and 135-lb. load, using cups with original roughness of 14, 28, and 35 microinches (rms). Such operation brought the roughness of the cups fairly close together. It was also noted that while the run-in wear tended to increase with increase in roughness, the final rate of wear was practically independent of the original surface roughness over the range covered. Comparable data may therefore be obtained even when reasonable differences in the surface roughness of the cups exist.

Besides offering a sensitive measure of the rate of wear with different commercial gear lubricants, the new test provides evidence of run-in wear which is of considerable importance. This should be taken into account in the evaluation of lubricants with respect to wear. Still another advantage is that the rate of wear after the run-in period is not materially affected by the original roughness of the test cups, as is the case with the usual load-carrying capacity tests with this machine.

The lubricants containing the more chemically active additives for withstanding higher shock load tend to show the greater wear. This is in agreement with the known service performance of some of these lubricants, particularly the active-sulphur lubricant and the nonadditive mineral oil.

A Permanent Standard of Neutron Intensity

WASHINGTON, D. C.—The National Bureau of Standards has recently developed a primary neutron standard which makes it possible for all laboratories to measure neutron radiation intensities in terms of a common reference value. The neutron standard consists of a solid beryllium sphere, 4 centimeters in diameter, enclosing at its geometrical center a capsule of radium. The capsule is made of platinum-iridium closely fitted to a gram of radium bromide compressed to maximum density. Neutrons are produced in the beryllium sphere by the action of gamma rays from the radium. Preliminary measurements indicate that the standard emits 1.1 million neutrons per second. The rate of neutron emission will change slowly as the radium decays, but this change is only about 0.04 percent a year and can be taken into account with sufficient accuracy.

A duplicate standard has been prepared for loan to other research laboratories requiring standardization of their neutron measurements. The standard is ready for use and any future revision in the neutron emission rate will result in only a small correction to any data based on the present provisional value. If, as has been suggested, the unit of neutron intensity is defined in terms of the new standard, it will then be possible to express measurements from different laboratories in directly comparable units.

The establishment of a national neutron standard has been made imperative by the increasing importance of neutrons as bombarding particles in physical and biological research. Since neutrons are uncharged particles, they can lose energy only by direct impact with nuclei. Fast neutrons with energies from 100,000 to about 15 million volts can pass through large masses of matter without much absorption or energy loss, being similar in penetrating power to very high-energy x-rays. The absorption mechanisms are different, however. The absorption of neutrons increases in proportion to the concentration of nuclei in the absorber, while that of x-rays increases in proportion to the overall density. Good neutron absorbers, such as water and paraffin, have a large concentration of hydrogen nuclei.

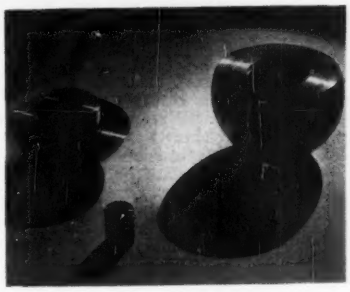
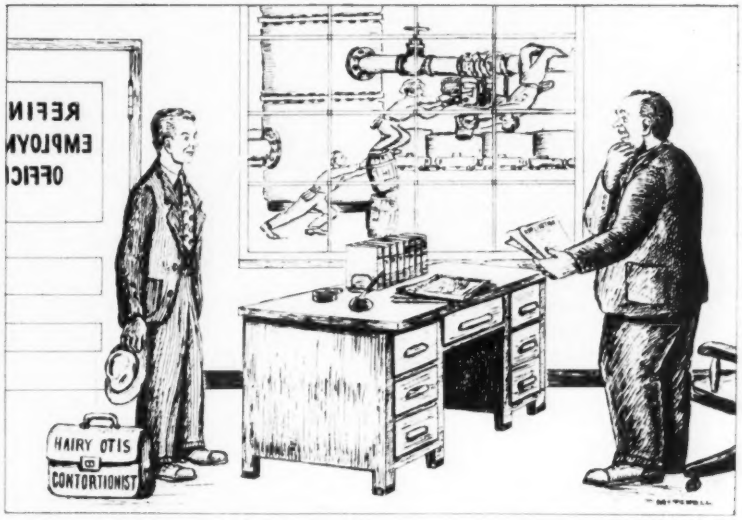


Fig. 1. Photograph, reproduced here exactly one-half actual size, of the neutron standard recently developed by the NBS. It consists of a solid beryllium sphere, 4 centimeters in diameter, enclosing at its geometrical center a capsule of radium.

Instru Merriment



"On second thought, I believe we can use you in our Instrument Department."

By S. E. Mitchell, Carbide & Chemicals Corp., S. Charleston, 3, W. Va.

The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control — in the form of concise technical descriptions.

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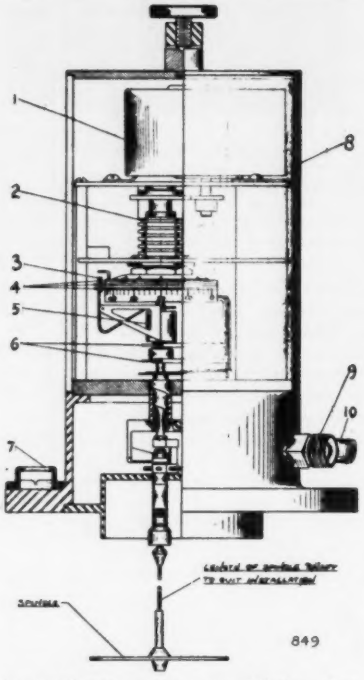
Automatic Viscosity Controller

New "Viscotrol" automatic viscosity controller has a range of 2 to 50,000 centipoises. It will respond to viscosity changes to within 1 percent of set-point value. Operation is based on



(1) Synchronous motor. (2) Collector rings. (3) Contact Arm. (4) Insulated disks. (5) Solenoid. (6) Torsion Springs. (7) Bubble level. (8) Removable Cover. (9) Purge inlet. (10) Nine-wire conductor to control box.

the fluid resistance to a synchronous-motor-driven spindle which energizes a relay if there is a deviation from a predetermined set point. Process control may then be attained with a solenoid valve. Motor and working parts are enclosed.—*Brookfield Engineering Labs Inc., Stoughton, Mass.*

Mention No. 301 when filling out card.

Fused-in-glass Resistance Thermometers

New glass unit supplements maker's fused-in-quartz high-speed resistance thermometer units, has similar characteristics. It comprises a tungsten or moly wire of small diameter with a thin glass coating. Resistance wire is wound closely on this structure and then another coating of glass is applied. Finished structure is about 0.1 in. in diameter and 3.5 in. long. Ice point resistances of 50 and 100 ohms are available; average temperature coefficient 0.5 percent per degree C. Units can be used up to 500 C. Speed of response is approx. 1 second for 63 percent change. New units can be introduced into small spaces on account of their small diameter.—*Paul G. Weiller, 95 Broad Street, New York 4, N. Y.*

Mention No. 302 when filling out card.

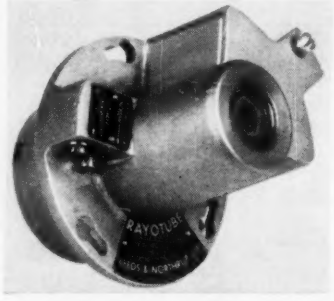
Portable Temperature Recorder

New "Model 81JM120" recording thermometer for refrigerated trucks, etc., has a dust and moisture-proof case, a counterbalanced recording mechanism which is unaffected by vibration, and a supersensitive thermal system. Instrument can be supplied with a built-in cylinder-type lock for positive protection. It comes equipped with stainless-steel capillary and 24-hour or 7-day chart-drive mechanism, and is available in ranges of minus 40 to plus 120 F. (7-day chart only) or minus 20 to plus 60 F. (24-hour chart only).—*Taylor Instrument Companies, Rochester 1, N. Y.*

Mention No. 303 when filling out card.

Hermetically-sealed Receiver for Radiation Pyrometry

New Model of "Rayotube" has quick-sighting optical system which lets user select desired target easily, and then check sharply-defined area which the Rayotube sees. Hermetically sealed construction at lens, window, and lead-

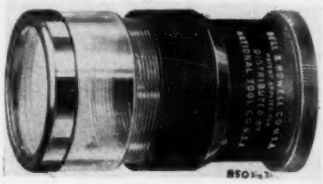


wires keeps out dust and gases. New design guards inherent accuracy and stability, even with high or rapidly changing housing temperatures. Unit is designed for easy, low cost replacement; fits all existing "Rayotube" mountings; requires no protection against high ambient temperature unless housing temperature exceeds 350 F. Below that point, any previously-installed water- or air-cooling can simply be turned off or disconnected.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

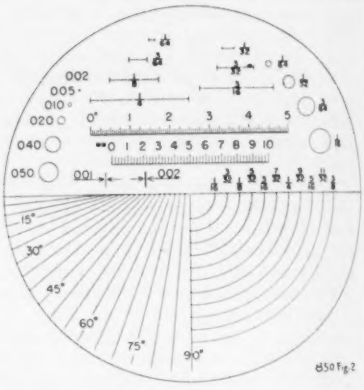
Mention No. 304 when filling out card.

Pocket Optical Comparator

New pocket-size optical comparator is useful in checking linear measurements, circles, angles, radii, etc. It has a 0.5 in. scale with 0.005 in. increments,



and a 10 mm. scale with 0.2 mm. increments. Fractional-inch steps are also included. Circles are included from 0.002 to 0.050 in. and in fractional-

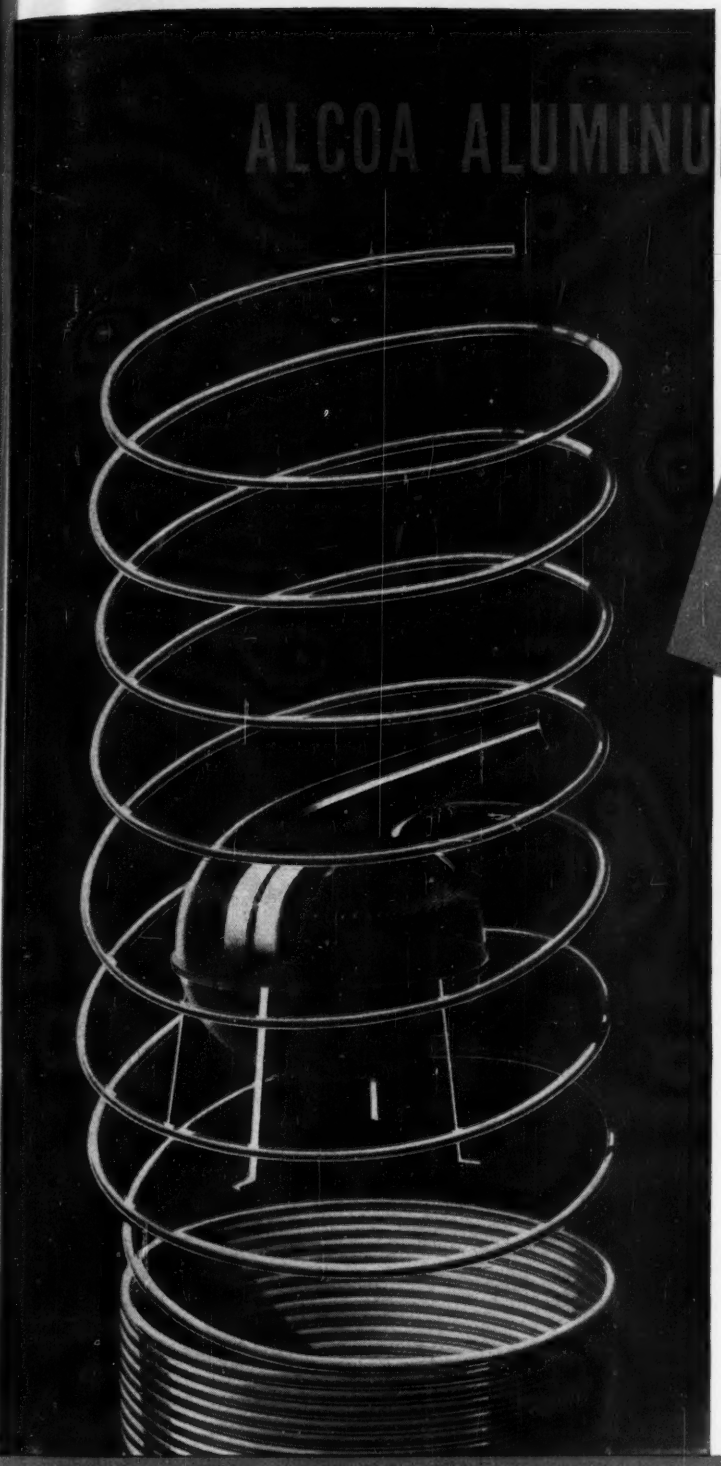


inch diameters. Angles from 0 to 90 degrees in steps of 5 degrees are measured and radii up to 0.375 inch.—*National Tool Co., 11200 Madison Ave., Cleveland 2, Ohio.*

Mention No. 305 when filling out card.

Extreme-sensitivity Color Comparator

New "Color-Eye" color-matching instrument is five times more sensitive than the human eye, uses a combined electronic and optical computing system to simulate response sensitivity and discrimination characteristic of human eye but without eye's variance in perception. States announcement: "Thus, for the first time industry is provided with a precise yet commercially practical standard for the measurement of color samples." In operation, instrument automatically "accommodates" itself to illumination level of samples being compared, just as human eye accommodates itself through iris diaphragm, retina, and brain. Range of automatic accommodations is such that sensitivity exceeds that of human eye for variations in brightness of 10,000 to 1. This permits comparison of samples reflecting only



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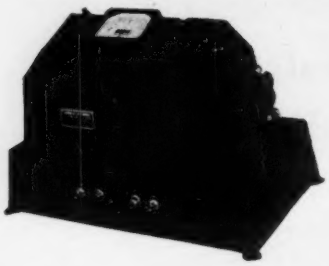
2 percent to an accuracy of 0.5 percent of reflected light. For evaluation of tristimulus color values relative to standard whites, "Color-Eye" is equipped with a micrometric slit and direct-reading scale from 0 to 100 percent. To make certain that surface conditions and illumination are comparable

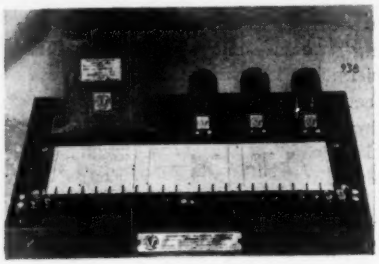


to visual measurements, prior to actual color measurements, samples may be examined with "Sample Viewer" accessory, which fits into transmission slide and is useful in making precise measurements of many types of surfaces, particularly where dark colors are encountered. "Color-Eye" may be carried anywhere in the plant for on-the-spot sampling. Special preparation of samples is usually not necessary because instrument will handle samples from 0.5 in. in diameter and up.—*Instrument Development Laboratories, 163 Highland Avenue, Needham Heights 94, Mass.*

Mention No. 306 when filling out card.

Demonstration Magnetic Amplifier

New demonstration magnetic amplifier is arranged so that all basic single-phase self-saturating circuits may be studied. By arrangement of external connections either d-c. or a-c. output is available and either d-c. or a-c. control power may be used. As

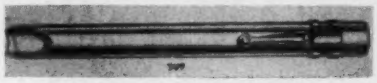


characteristics of amplifiers connected for d-c. and a-c. output and control differ, it is important that all of these circuits and their combinations be studied. Unit may be used in operating control circuits, such as voltage regulators for small a-c. and d-c. generators, speed control for small d-c. motors, controlled-rectifier power supply, and closed-loop positioning systems commonly employed in servo-mechanism work. Reference material, bulletins, technical data on application, and use and performance characteristics of magnetic amplifiers is included with each unit.—*Vickers Electric Div., 1815 Locust St., St. Louis 3, Mo.*

Mention No. 307 when filling out card.

Pocket Microscope

New pencil-size microscope has a magnification of 20 dia. with 4 lenses.

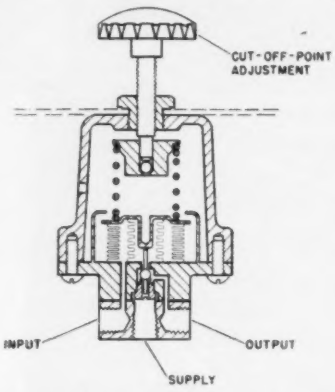


Body is aluminum, 5 in. long, and weighs less than 1 oz.—*Harry Ross, 70 W. Broadway, New York 7, N. Y.*

Mention No. 308 when filling out card.

Snap-action Pneumatic Relay

New pneumatic relay for use with air-electric switches and other equipment requiring high-speed operation provides sharp cut-off action. Cut-off point can be set for any pressure between zero (atm.) and 35 psig. Overloading with input pressures up to 70 psig. will not damage relay. Supply pressures as high as 50 psig. may be



used. High amplifying ratio makes a small change in input pressure cause full change in output. When relay is used with maker's Pneumatic Comparator Gage (0.0004 in. full-scale) and a commercial pressure switch, it operates a signal light on a dimension change as small as two microinches. Standard instruments are furnished for direct action: increase of input pressure causes increase of output pressure. Special instruments for reverse action may be furnished.—*Moore Products Co., H and Lycoming Sts., Philadelphia 24, Pa.*

Mention No. 309 when filling out card.

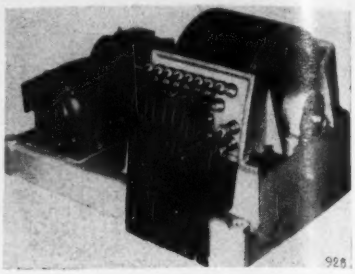
Industrial-liquids Densitometers and S. G. Controllers

New line of "Pycnorator" instruments for measurement and control of fluid density and specific gravity has been introduced. Various designs available are submerged-float instruments for use in vessels under pressure or vacuum, open-bubblers, closed-diaphragm and hydrometer types. Instruments are also available which operate in conjunction with "Ranarex" specific-gravity measuring system.—*Fisher & Porter Co., 76 County Line Road, Hatboro, Penna.*

Mention No. 310 when filling out card.

Magnetic Data-storage Systems

New magnetic data-storage systems utilizing rotating magnetic drums are available in either standard or custom-built models, saving costs and space, and adding flexibility, in computing,

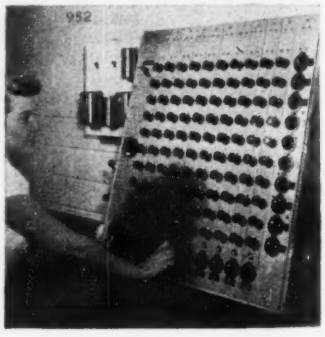


inventory and automatic-control systems to replace storage relays, stepping switches, punched tape and other bulky forms of storage. Storage capacity as high as 1280 magnetic marks per square inch may be attained. 120,000 groups of marks per second may be read from drum. Permanence of record is assured even during a momentary power or equipment failure.—*Engineering Research Associates, Inc., 1902 W. Minnehaha Ave., St Paul 4, Minn.*

Mention No. 311 when filling out card.

Ten-equation Electrical Computer

New "66 Spectro Computer" solves, by iteration method, simultaneous linear equations of the type encountered in infrared and mass spectrometry; utilizes d-c. potentials substituted for the unknowns. Multiplication, division, ad-



dition and subtraction steps necessary in solving a spectroscopic analysis problem involving as many as ten simultaneous equations can normally be performed by new computer within 5 to 30 minutes. Results of spectroscopic analysis of hydrocarbon samples have been computed to an accuracy of 0.1 percent with this instrument.—*Special Products Div., Phillips Petroleum Co., Bartlesville, Okla.*

Mention No. 312 when filling out card.

X-Y Recorder

New "Model 205 Variplotter" records one variable as a function of another. Plotting surface is 30-in. square glass with back lighting. Sensi-

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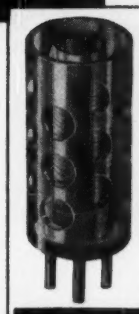

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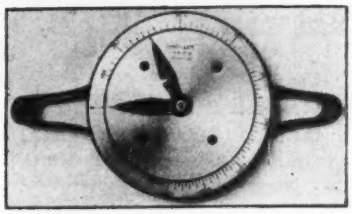

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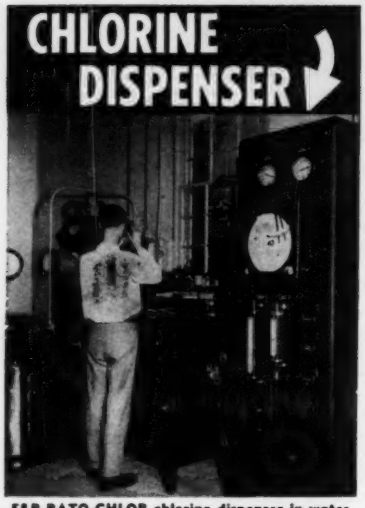

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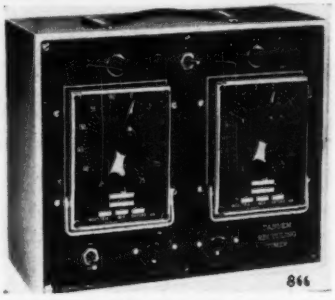
tivity is 50 mv. per in. with other ranges available. Accuracy is 0.05 percent full scale at 68 F. static, and 0.1 percent dynamic. Pen-traverse time is 3 sec. full-scale for either dimension. Timing marks may be provided for. One power supply and two servo amplifiers are used. Dimensions 47.5 by 44 by 42 in.; weight 615 lb.,—*Electronic Associates Inc., Long Branch, N. J.*

Mention No. 313 when filling out card.

Dual Sequence Timer

New sequence timer enables two operations of different time intervals to be carried out in succession with indefinite repetition of cycle. Load-relay



contacts are rated at 20 amps. at 115 v., 60 cps. non-inductive. Cabinet is complete with on-off switch, load-control switch, pilot lamps and outlets.—*Industrial Timer Corp., Newark, N. J.*

Mention No. 314 when filling out card.

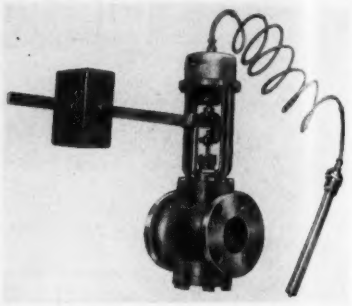
Millisecond Timer

New "Chronotest Electronic Millisecond Timer," for measuring intervals between 0.1 millisecond and 10 seconds with an accuracy of 1 to 2 percent, is available in two models, one with a top range of 1 second in six steps and one with a top range of 10 seconds in six steps. Instrument operates from line voltages of 110-250-volts, 40-100-cycles single-phase. Readings are obtained on a scale approx. 4½ in. long. Basic principle is said to be a variant of capacitor charging circuit "incorporating refinements and safeguards which several years of development has shown to be desirable." Instrument is made in England.—*Herman H. Sticht Co., Inc., 27 Park Place, New York, N. Y.*

Mention No. 315 when filling out card.

Temperature Regulator

New thermostatic regulator uses vapor-bulb type of control valve. Adjustment of control temperature is made by a weight and lever arrangement. Lever arm permits settings, within a 40 F. range, 20 F. over and

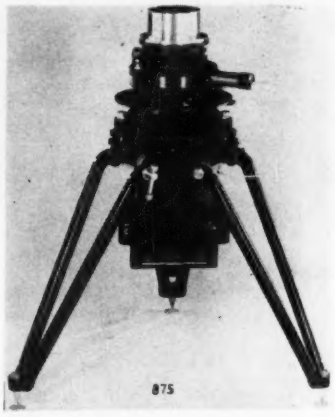


under a given control point. Temperature ranges are available from 40 to 200 F. Sizes available are 0.25 up to and including 2 in. bronze body union ends; 2.5 to 5 in. from body, flanged.—*Lawler Automatic Controls, Inc., 453 N. MacQuesten Parkway, Mount Vernon, N. Y.*

Mention No. 316 when filling out card.

Celestial Surveying Camera

New Zenith camera is fitted with a Goerz-Dagmar f4.5 lens, having a focal length of twelve inches and resolution of 40 lines per mm. To operate, instrument is set up and leveled. Two ex-



posures are made on a single plate at an interval of but a few minutes. From known positions of star images in celestial sphere, coordinates of point may then be computed. This computation establishes primary-control point on earth's surface with an accuracy of 50 feet.—*West Coast Div., Fairchild Camera & Instrument Corp., 53 W. Union St., Pasedena, Calif.*

Mention No. 317 when filling out card.

Time Cycle Controllers

Five new models of maker's "Flex-O-Timer Time Cycle Controllers" are available for applications requiring all-electrical or all-pneumatic, or any specified combinations of each. They con-

trol any particular group of functions which may be required in the sequence of a manufacturing operation—according to a predetermined schedule and over a specifically timed period.—*Taylor Instrument Companies, Rochester 1, New York.*

Mention No. 318 when filling out card.

Recording Camera

New Model of "Varitron" Industrial Recording Camera (originally described in our May 1949 issue, page

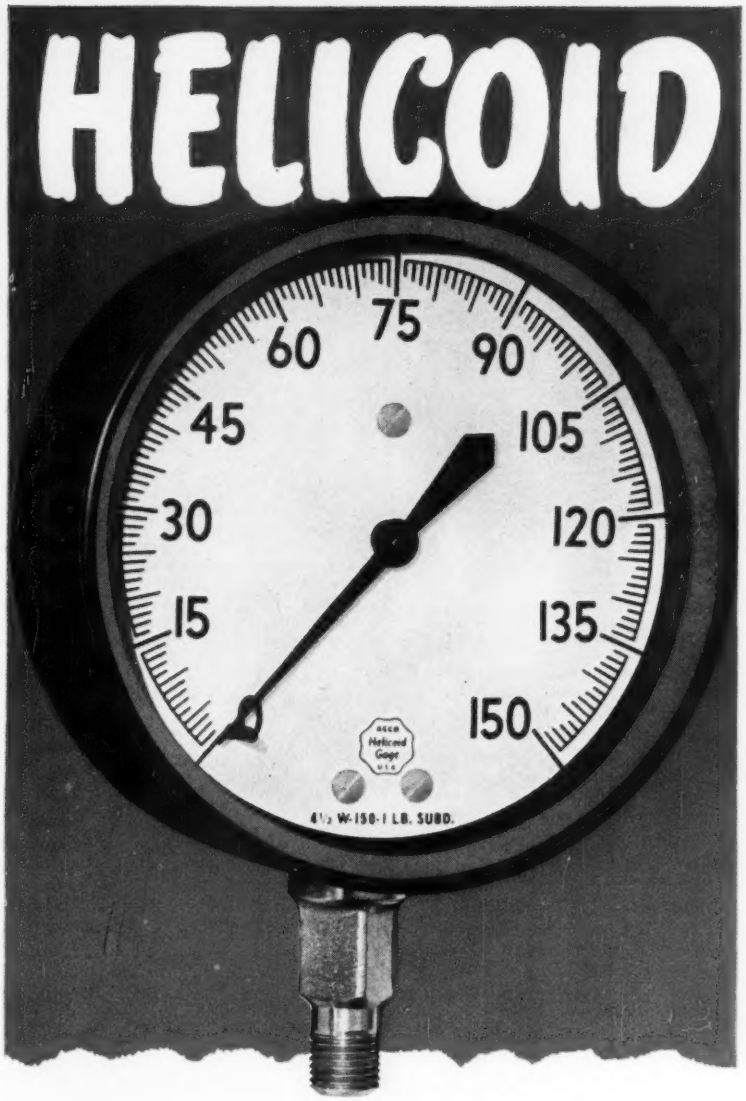
420) has a 30" taking lens. Another feature is an extra-large recording chamber, approx. size of camera itself. —*Photographic Products Inc., 955 N. Mansfield Ave, Hollywood 38, Calif.*

Mention No. 319 when filling out card.

Ceramic-body Control Valve

New "Merit" valve has body made of a newly developed ceramic suitable for continuous 300-psi. operation at temperatures up to 2000 F., to control flow of corrosive fluids with exception of hydrofluoric acid and hot-alkali concentrate. Valve bodies are machined from a solid slug of ceramic prior to

firing. Body has a hardness 0.9 that of diamond, with tensile strength of 27,000 psi. and compressive strength of 290,000 psi. Ceramic will not absorb moisture. Teflon packing rings are used as seals. Valves are available in 0.5, 0.75, 1, 1.5, 2, and 3-inch sizes, designed for attachment to 300-lb std. ASA flanged fittings by means of



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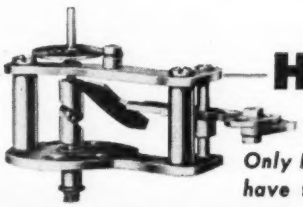

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SAFETY ALARMS
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DROP WIRE DETECTION

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products co
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stainless-steel cap screws. Stainless-steel studs can be mounted in body if desired. Diaphragm and hand-operated types (lubricated or unlubricated) are available.—*Emmett Machine & Mfg. Co., 2249-51 14th St., S. W., Akron 1, Ohio.*

Mention No. 320 when filling out card.

Lubrication Signal for Automotive Vehicles

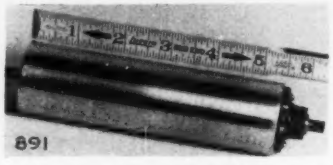
New signal device, designed to operate by friction with odometer in speedometer, has flag that comes into view across odometer window every 1,000

miles, thereby brings need for lubrication at regular intervals to attention of operator. By means of a small manually-operated control button, it can be returned to its original position. Signal flag (illustrated) is made of a transparent colored material to permit reading of milage figures.—*Howard L. Berry, 1134 Glenwood Boulevard, Schenectady, N. Y.*

Mention No. 321 when filling out card.

Small Servomotor

New velocity-servo torque unit for use in velocity servos and motor integrator systems consists of a permanent-magnet-field type 27.5-volt armature d-c. motor to which whose high-speed shaft (10,000 rpm. maximum) has coupled a permanent magnet field type d-c. rate generator. A 250-rpm. maxi-



mum low-speed output shaft is coupled to motor through suitable gear reductions. Unit may also be incorporated into position type servo systems using motor coupled to separate followup device and tachometer for error rate stabilization. Torque unit motor supplies an output torque of approx. 6 in.-oz.; tachometer output voltage is available in various models at from 2 volts to over 10 volts per 1000 rpm. of motor speed. Special models available.—*Servo-Tek Products Co., 4 Godwin Ave., Paterson 1, N. J.*

Mention No. 322 when filling out card.

Indicators for Thermoelectric Pyrometry

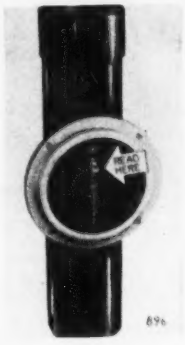
Three new sizes of millivoltmeters for panel mounting have unbreakable clear-plastic one-piece front covers. Eight ranges cover temperatures from minus 75 F. to 3000 F., minus 60 C. to 1600 C., both F. and C. are shown on dials. Standard calibrations for Chromel-Alumel and for iron-Constantan

couples; other types including platinum couples on special order. Instruments have automatic cold junction compensation, 250 microamperes full-scale sensitivity or four ohms per millivolt; adapted to various lengths of thermocouples from a few inches up to 100 feet or more.—*Assembly Products, Inc., Chagrin Falls, Ohio.*

Mention No. 323 when filling out card.

Flow-rate Indicator

New design of "Magna-Sight" flow indicator which uses variable-area principle allows opaque liquids or slurries to be measured through use of a permanent magnet on metering

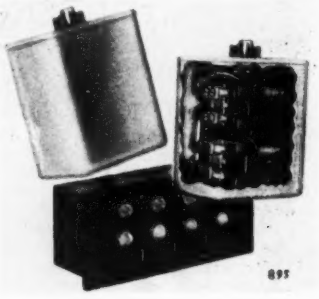


plug, which positions a soft-iron follower in a slot external to flow channel. Indicator is available in brass, bronze, iron, steel, and 316 stainless in sizes from 0.75 to 4 in. with max. rates from 3.5 to 250 GPM. Temperatures up to 400 F., and pressures up to 500 psi. are permissable.—*Fischer & Porter Co., 96 County Line Rd., Hatboro, Pa.*

Mention No. 324 when filling out card.

Multiple-signal System for Hazardous Locations

New "Series 400" alarm units have hermetically-sealed relays on a sealed plug-in octal socket, and comply with National Electric 1947-Code specifications for Class 1, Div. 2 installations.

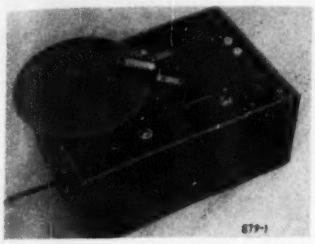


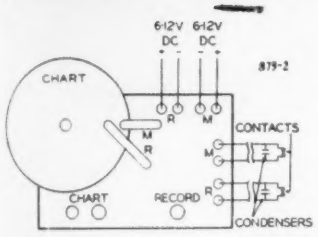
Typical operation: alarm conditions, both lights bright, horn sounding; operator presses acknowledging button, white light off, red light on, horn silent; normal operation, white and red light both dim, horn ready to sound again. A single horn will serve any number of stations.—*Panalarm Products Inc., 7216 N. Clark St., Chicago 26, Ill.*

Mention No. 325 when filling out card.

Time-interval Recorder

New recording chronograph for intervals from nearly 0 to 33 milliseconds, or greater, is designed primarily to time flight of bullets. Passage of bul-



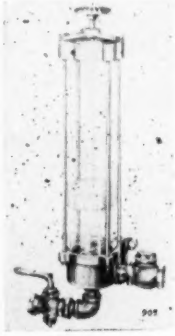


let through two wire screens is recorded as spark holes in paper disk rotating at 1800 rpm. Other applications are readily made. Current requirements are 115 v., 50-60 cps. and 6-12 v., d.c.—*Theodore M. Long, 40 S. Bridge St., Somerville, N. J.*

Mention No. 326 when filling out card.

Chemical Feeder-blender

New "Hydro-blender" for introduction of chemicals that will "wet" water at point of use is made of brass and a tube of Lucite, and weighs approx. 35 lb. Chemicals are placed in Lucite tube in form of water-soluble capsules. There



they dissolve in proportion to water passing through a built-in Venturi nozzle. When used with 3-lb. capsule, resulting solution has a surface tension of 30 dynes. Each capsule makes a minimum of 1000 gallons of "wet water" (reduces surface tension from

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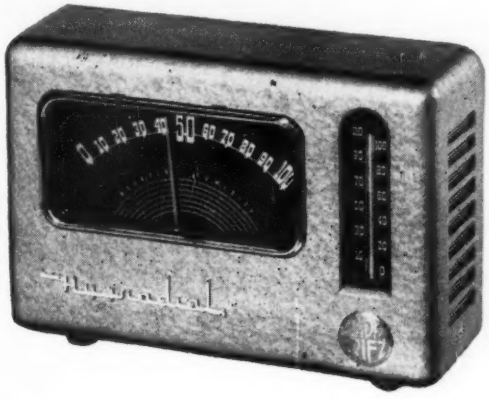

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The "extended range" adds new versatility . . . makes the instrument an even more valuable tool for precision process applications. For example, a wide range scale can be used for readings starting with ambient temperatures and continuing up to "on stream" temperatures. Once on stream, a narrow range scale is used to obtain extremely accurate readings, taking full advantage of the inherent accuracy ($\pm 1/5\%$) of the instrument. In addition to this pin-point readability, you get one instrument that will do the work of two . . . saving valuable panel board space.

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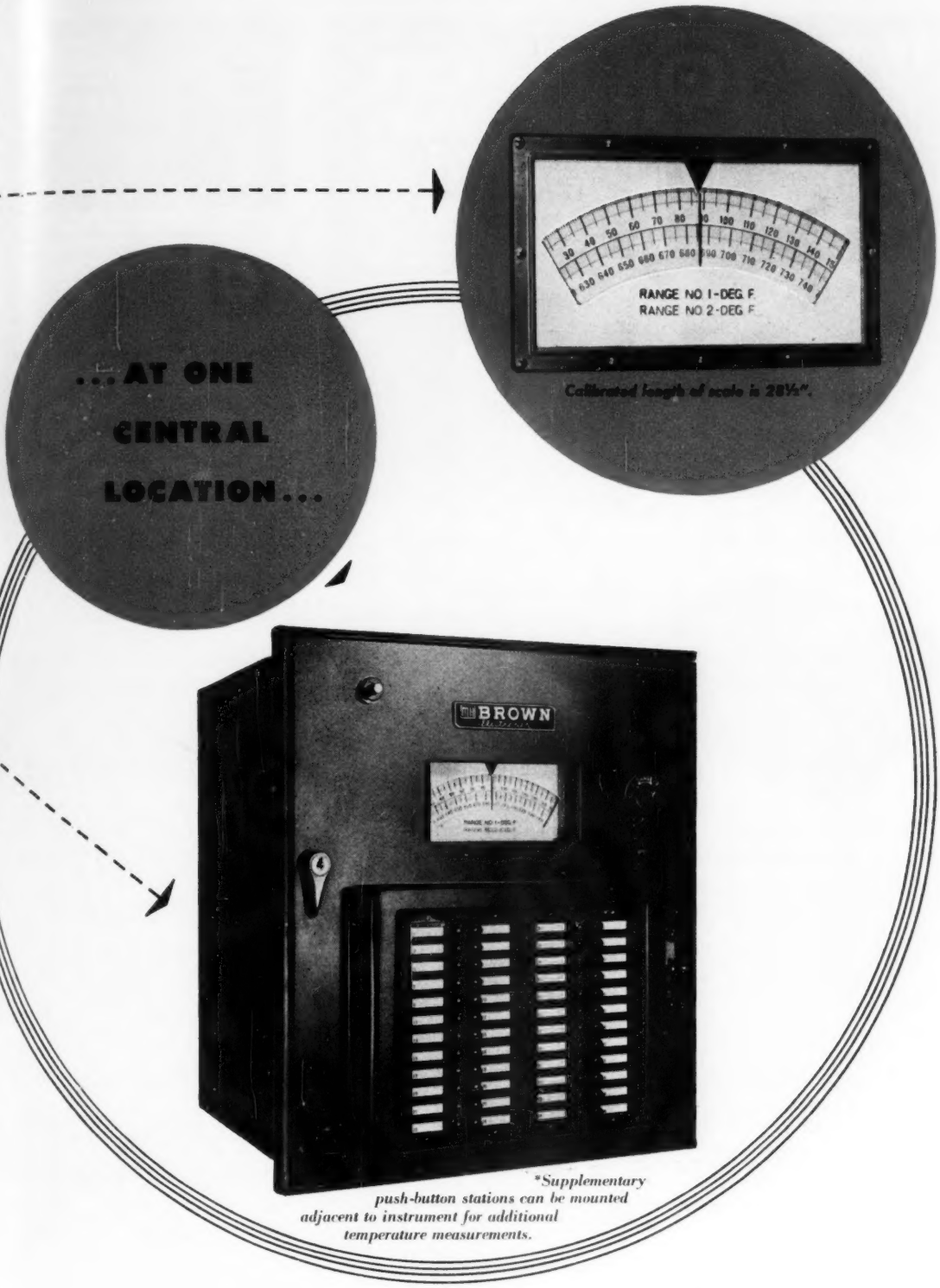

*Supplementary push-button stations can be mounted adjacent to instrument for additional temperature measurements.

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accurately, simply and permanently

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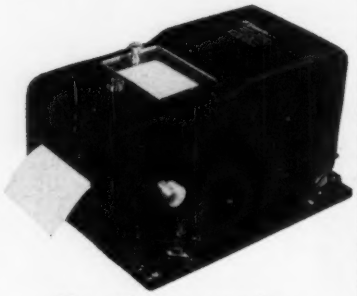

No other recorder offers these features:

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- Without amplification, operate directly from Giannini potentiometer transmitters, a-c or d-c positioning devices, or other transmitters delivering 10 milliamperes—
- With amplification, record output of strain gages and thermocouples, and are—
- Available with 1, 2, 3 or 4 channels plus a reference marker, providing up to 5 channels of test information, and are—
- Driven from governed 24 volt, d-c motor or from other voltage as required.
- Three chart speeds—may be changed with recorder in full operation.

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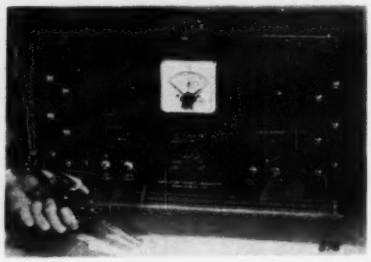
72 to 30 dynes). Most efficient spraying pressure is between 60 and 75 psi. Above 100 psi. a pressure reducer is recommended. Less than 25 psi., a booster pump should be used.—*Aquadyne Corp., 220 E. 42nd St., New York 17, N. Y.*

Mention No. 327 when filling out card.

High-vacuum Gage

New "DPA-38," ionization gage allows full-life use of maker's "VG-1A" tube. Lowest scale division represents 0.002 millionths mm. Hg. Instrument

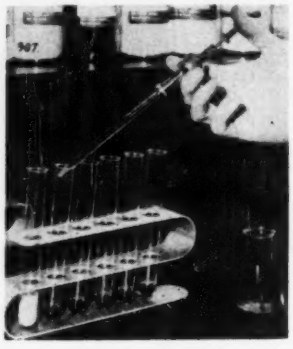


features a direct-reading scale where negative exponent of number of mm. is read on range selector and coefficient is read on dial. Automatic relay assures max. life for ionization tube. Unit operates on 110-v. 60-cps. line.—*Distillation Products Industries, Ridge Road West, Rochester 3, N. Y.*

Mention No. 328 when filling out card.

Semi-automatic Pipettes

New automatic pipette for any volume up to 2.0 ml. allows operator to pipette 20 to 30 times per minute. Four slots and a vernier set stroke of



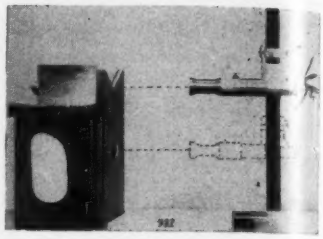
plunger to deliver an exact volume.

New "Micropette" for volumes up to 0.7 ml. has a sliding-sleeve and setscrew arrangement by means of which any pre-set volume can be expelled. Using distilled water, it has been found that accuracy of liquid dispensed is within plus or minus 0.001 percent.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 329 when filling out card.

Shop Cathetometer

New "Height Gage Scope" cathetometer has dash-lined crosshair which will distinguish 0.001 in. at two feet, and has a concentric circle for picking

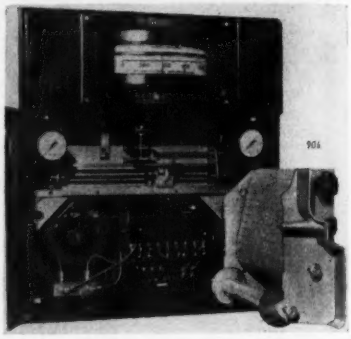


up hole centers. Measurements are read directly on height-gage vernier. Instrument may be focussed from 2.5 in. to infinity. It is 9.25 in. long, 1.438 in. dia., and weighs 12 oz.—*Quality Control Co., 6356 Hollywood Blvd., Los Angeles 28, Calif.*

Mention No. 330 when filling out card.

Strip-chart Recorder-controller

New "Pneumatic Capacilog" air-operated strip-chart recorder is completely self-contained and has only two

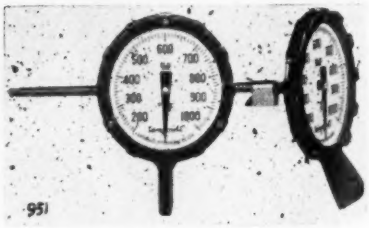


external-air connections. Instrument uses maker's "Capacilog" and "Electronic Link" circuits.—*Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.*

Mention No. 331 when filling out card.

Dial Thermometer

New "Tempoint" dial thermometer for indicating temperatures from 200 to 1000 F. comprises a three-inch diameter body and a stainless steel stem, 5.5 inches free length (2 inch immersion to obtain accurate readings). Bezel is high-temperature Bakelite;



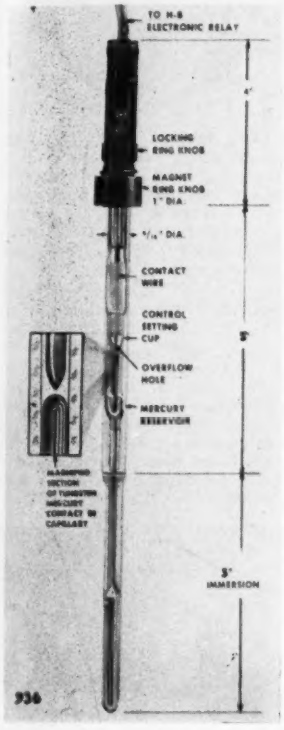
glass window is sealed with a silicone gasket to keep moisture and dust from scale. Exceptional readability is claimed to be given by V-shaped bright-red pointer, unusually large non-glare scale with correspondingly large numerals. Accuracy guaranteed, 1 percent of range at any point of indication. Novel

sleeve holder on stem permits mounting over a hole without tools. Handle is integral part of bezel.—*Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.*

Mention No. 332 when filling out card.

Thermoregulator

New "Quick-Set" Thermoregulator has a control setting which can be varied over a wide range in a matter of seconds. Once set within 10 F. of control temperature, adjustments of

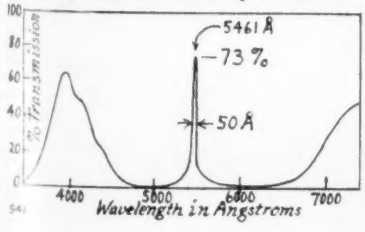


several degrees down to 0.01 and even smaller under favorable conditions, are made by turning a ring knob. One model covers a range from approx. 30 to 600 F. or higher. Another model covers a range from minus 38 F. to about 50 F. Over-all length is 14 in.—*H-B Instrument Co., Dept. T-19, 2633 Trenton Ave., Philadelphia 25, Pa.*

Mention No. 333 when filling out card.

Narrow-bandwidth Green Filter

New mercury-green multilayer-interference filters, available in 2-in. and 1-in. squares, meet rigid specifications: peak wavelength of 5461 plus-or-minus 10 A.u.; transmission 70 plus-or-minus



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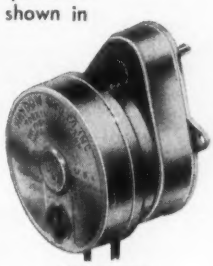
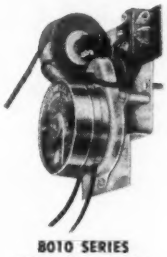


4400 SERIES

INTERVAL TIMER WITH BUZZER

This timer features an optional buzzer; demands attention by sounding continuously after completion of cycle until manually turned off. Unusually compact, for use where space is limited; offered in a wide range of intervals.



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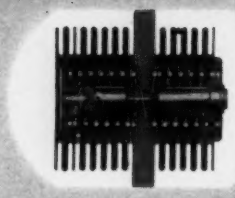

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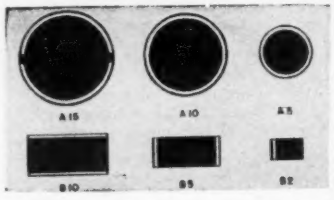

Cell	Size	Output-μa*
A15	2" diam.	800
A10	1¾" diam.	550
A5	1⅛ diam.	250
B10	1-11/16"x7/8"	340
B5	1-7/16"x41/64"	220
B2	23/32"x7/16"	75

*At 100 ft.—Candles & ext. Resistance of 100-ohms

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10 percent; bandwidth 50 plus-or-minus 10 A.u. at half max. transmission.—*Baird Associates, 33 University Road, Cambridge 38, Mass.*

Mention No. 334 when filling out card.

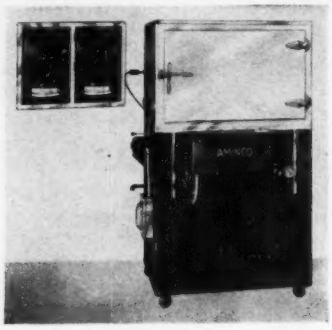
Multi-channel Airport Recorder

New magnetic recorder, capable of recording fourteen channels simultaneously, is made to mount on three 7.5-foot standard relay racks. Each reel of recording tape will run for slightly over four hours and will automatically start a second reel before first is finished, giving up to eight hours of unattended operation. Automatic starting of a standby recording system and special alarm circuits assure against failure.—*Brush Development Co., Cleveland, O.*

Mention No. 335 when filling out card.

Humidity-temperature Test Apparatus With Program Control

New humidity-temperature test apparatus consisting of a test chamber, an air-conditioning unit, and a special control system has an average max. rate of rise of dew-point temperature

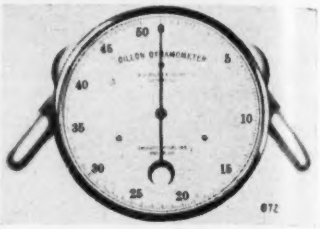


of 0.45 F. per min. between 60 and 160 F. at no load, with an average max. fall of 0.75 F., and has average max. rise and fall of dry-bulb temperatures equal to or greater than those for dew point.—*American Instrument Co., 8030-8050 Georgia Ave., Silver Spring, Md.*

Mention No. 336 when filling out card.

Traction-type Dynamometers

New ranges of "Model AN" dynamometers add units of 30, 40, and 50 thousand-pound capacity for measuring tension loads. Dial diameter is 10 in., net weight is 25 lbs. Instrument will

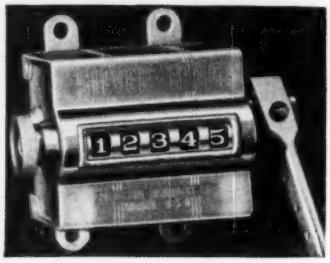


stand 15 percent overload without damage to calibration, and will hold a 2-times overload. Inside dimensions of shackles are 3.875 by 2 in. Instrument is calibrated against laboratory testing machine, and checked with proving ring certified by U. S. Bureau of Standards.—*W. C. Dillon and Co., Inc., 5410 W. Harrison St., Chicago 44, Ill.*

Mention No. 337 when filling out card.

Stroke Counter

New "Silver King" mechanical counters incorporate steel base and cover with chromium finish, light-weight plastic number wheels for reduced inertia and windows of reinforced plastic. A built-in device prevents reverse op-



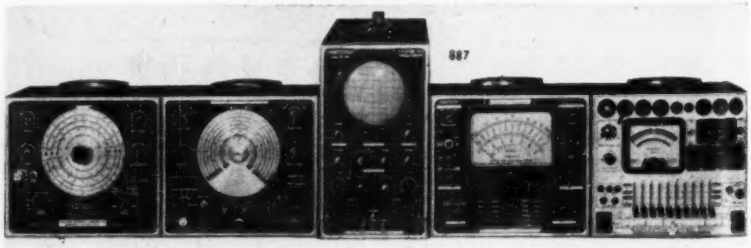
eration of reset mechanism. Any tampering with reset knob is easily detected. Counters are also available in key-reset and non-reset models.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.*

Mention No. 338 when filling out card.

AM-FM-TV Testing Instruments

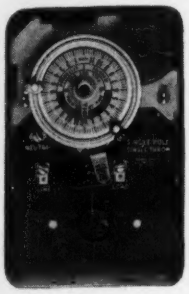
New AM-FM-TV testing and service laboratory consists of a set of five matched instruments: Marker-signal Generator; Sweep-signal Generator; Cathode-ray Oscilloscope; VTVM-megohmmeter and a tube tester.—*Precision Apparatus Co., Inc., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Mention No. 339 when filling out card.



Time Switches

New "Series TS50 Inter-Matic" time switches feature interchangeable-switch assemblies, conversion to portable plug-in units as desired, and up



to 12 on and off operations every 24 hours. Units are mounted in drawn-steel round-corner cabinets 7.75 by 5 by 3 in. with 0.5 and 0.75 in. knockouts in sides, back, and bottom. Switch contacts are rated at 35 amps.—*International Register Co., 2624 W. Washington Blvd., Chicago 12, Ill.*

Mention No. 340 when filling out card.

Tension Meter

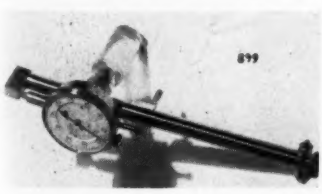
New "Tensiometer" yarn tension indicator has a transparent flywheel through which readings are taken which makes steady readings possible

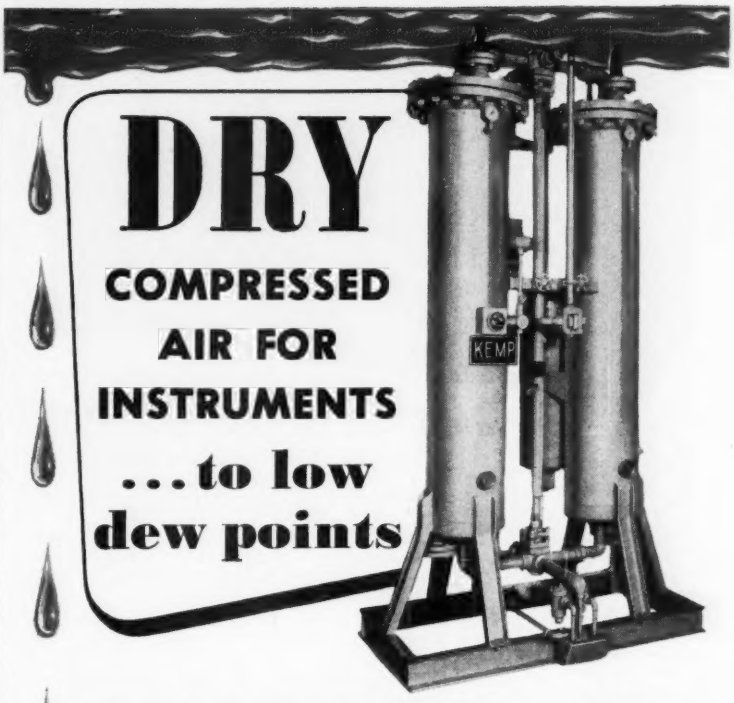
on quickly traversing machinery. New model has total capacity of 125 grams. Fifty grams are read from black figures on first revolution of dial. Remaining 50 to 125 grams are read from red figures on second revolution.—*Saxl Instrument Co., Harvard, Mass.*

Mention No. 341 when filling out card.

Dial Bore Gage

New "Series S and T" dial-type bore gages are made to measure diameters from 0.5 to 6 in. or other ranges on special order. First model gives direct readings in thousandths over entire range; second gives plus or minus in-





Here's how KEMP Dynamic Dryers protect instruments, control moisture in instrument air at Low Cost!

COMPACT, inexpensive, standardized — that's the story behind Kemp Oriad *instrument* air dryers. Designed specifically for instruments, these dryers limit moisture content in instrument air to safe dew points! Operation is *uninterrupted*. One single lever changes flow and reactivation is accomplished automatically. Oriad Dryers are available in standard drying cycles.

DESIGNED FOR INSTRUMENTS

Kemp Dynamic Dryers are versatile—offer *manual, semi-automatic* or *automatic* operation. Drying to any *dew point you specify* is guaranteed, at an extremely low cost! Desiccant is selected especially for instrument work to provide effective moisture control. Choose gas, electric or steam regeneration as standard equipment.

SEND FOR INFORMATION

Whether your moisture control problem is special or standard, you'll find Kemp has a Dynamic Dryer especially designed to solve it. Find out how Kemp engineering can save you money. Get the facts on Kemp Dynamic Dryers. Bulletin D-27, contains specifications, technical data and full information. For free copy, mail coupon today!

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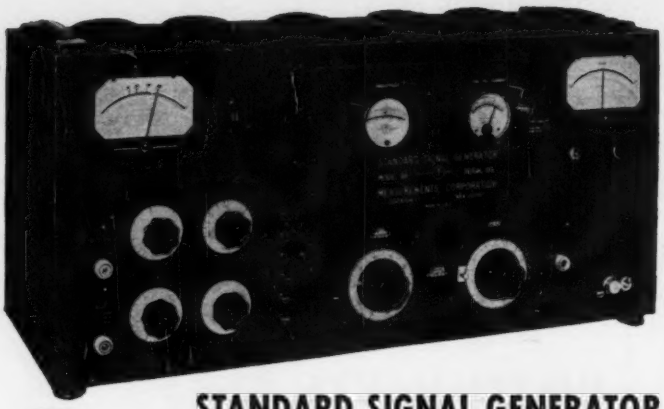
405 E. Oliver St., Baltimore 2, Md.

Gentlemen: Please send me Information Bulletin D-27. We want facts on drying ( ) air ( ) gas ( ) liquids.

Name .....
Company .....
Address .....
City ..... Zone ..... State .....



STANDARD SIGNAL GENERATOR

MODEL 84—300-1000 Megacycles

OUTPUT VOLTAGE: Continuously variable from 0.1 to 100,000 microvolts. Output impedance, 50 ohms.

MODULATION: Sine Wave: 0-30%, 400, 1000 or 2500 cycles. Pulse: Frequency, 60 to 100,000 cycles. Width, 1 to 50 microseconds. Delay, 0 to 50 microseconds. Sync. output, up to 50 volts, either polarity.

POWER SUPPLY: 117 volts, 60 cycles. (Also available for 117 volts, 50 cycles; 220 volts, 60 cycles; 220 volts, 50 cycles.)

DIMENSIONS: 12" high x 26" wide x 10" deep, overall.

WEIGHT: Approximately 135 pounds, including external line voltage regulator.

Laboratory Standards

Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Grid-Dip Meters
Television and FM Test Equipment

MEASUREMENTS CORPORATION

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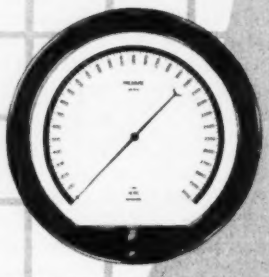
dial scale is always concentric with the pointer travel



HEISE GAUGES

STANDARD OF THE WORLD

The scales of Heise Bourdon tube pressure gauges are absolutely concentric with the pointer rotation. Errors due to misalignment in mounting or cutting the scales are avoided since the scales are cut from their centers, and are mounted at the centers on a hollow spindle through which the pointer rotates.

Three sizes: 8½ in., 12 in., and 16 in., in ranges from 0-15 to 0-10,000 psi. Prices from $151.60 to $211.20. Write for catalog.

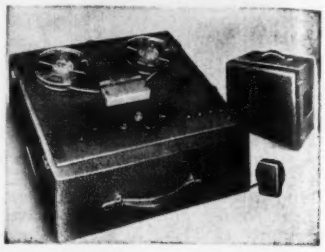
Heise Bourdon Tube Company, Inc.
Newtown, Connecticut

dications in tenths of thousandths for any dimension to which gage is set. Standard tip sizes are one-sixteenth and one-eighth in. O.D. Special tips are available for grooves down to 0.03 in. —*Rimat Machine Tool Co., 111 Air Way, Glendale, Calif.*

Mention No. 342 when filling out card.

Magnetic Tape Recorder

New "Knight" magnetic-tape recorder has a 1200-foot reel of tape which provides a full hour's recording



and is complete with a built-in high-gain amplifier and PM speaker for playback. A crystal handmike and cable, all tubes, and one half-hour spool of tape are supplied.—*Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.*

Mention No. 343 when filling out card.

Chemical-problems Circular Slide Rule

New "Chemputer," based on equipment originally developed for aerial navigation, consists of a pair of sliding

scales plus a hairline finder. A single setting of scales solves any problem of simple proportion.—*Coleman Instruments, Inc., 318 Madison St., Maywood, Illinois.*

Mention No. 344 when filling out card.

Tile Sorter

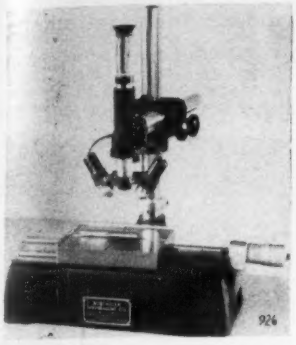
New "Model 203" electronic sorter is used to detect air pockets in tile. Equip-

ment may be used on conveyors for sorting at rates up to 10 per second.—*Electronic Associates Inc., Long Branch, N. J.*

Mention No. 345 when filling out card.

Toolmaker's Microscope

New "Model No. 1" microscope performs functions of linear, coordinate, and angular measurement. Range of measurement is 6.5 inches in each of

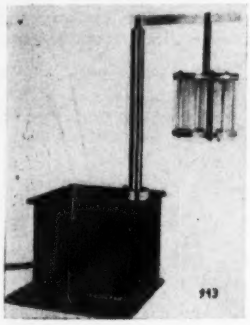


two coordinates. Angular measurements are made by linear determinations plus shop trigonometry. Optics consist of achromatic objective and Ramsden eyepiece. Over-all magnification is about 35 times. Standard equipment includes dust cover and gage rods.—*Boeckeler Instrument Co., 31 E. Rillito St., Tucson, Arizona.*

Mention No. 346 when filling out card.

Tablet Disintegration Tester

New "Stoll-Gershberg type Tablet Disintegration Tester" has a six-cell screen-bottomed carrier which is moved in a 5.5 cm. vertical stroke in and out of a constant-temperature bath at the



rate of 28 to 30 strokes per minute. It provides in one compact unit motive power to immerse carrier at a constant and fixed rate. New apparatus may be found useful with little adaptation for determining dissolving rate for soap and similar products, or for rusting tests of metals.—*J. J. Vanderkamp, 150 High Street, West Orange, N. J.*

Mention No. 347 when filling out card.

Testing Machine

New "Type LC" testing machine is provided with dual-capacity ranges of 10,000 lbs. and 1000 lbs. It meets Army, Navy, Federal and ASTM specifications, and is available in both hand-operated and motor-driven models. Hand-operated model is for bench mounting; motor-powered units are

Speedy • Accurate

RESISTANCE MEASUREMENTS

... with the Rubicon
PORTABLE WHEATSTONE BRIDGE

This convenient instrument combines instant portability with high accuracy and is widely used in laboratory, plant and field. Built for dependable service under hard usage.

- Wide range: 1 ohm to 10 megohms
- Limit of error: 0.1%
- Built-in battery and galvanometer
- Provision for external battery and galvanometer when required
- Available with Murray and Varley loop circuits
- Compact and rugged

... with the Rubicon
PORTABLE KELVIN BRIDGE

For work at very low resistance levels this instrument is the counterpart of the Wheatstone bridge shown above.

- Range: 0.0001 to 10.1 ohms
- Limit of error: 0.25%
- Built-in battery and high sensitivity "Pointerlite" galvanometer
- Provision for external battery and galvanometer when required
- Sturdy and convenient in operation

Wheatstone and Kelvin bridges in a variety of models, together with other resistance measuring instruments, are fully described in Bulletin 100 available on request.

SPOTLIGHT GALVANOMETER

- Sturdy, short period
- Sensitive (up to 0.0006 μA per mm.)
- Multiple-reflection optical system
- For null or deflection measurements

Described in Bulletin 320

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Electrical Instrument Makers

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2. Standard and special FM/FM subminiature components and assemblies.
3. Installation engineering and calibration services.
4. Aircraft and missile antenna design.
5. Flight testing, providing ground station facilities and reduction and analysis of data.

Indicative of the engineering leadership which Bendix-Pacific has attained is the fact that a typical six-channel telemetering system complete with power supply weighs 12 pounds and occupies only 130 cubic inches. Equipment now available to provide line of sight ranges up to 100 miles or more for Bendix-Pacific Telemetering Systems. Inquiries from qualified companies and agencies for complete engineering data are invited.

Plug-in components provide the utmost in flexibility for the instrumentation engineers in your company.

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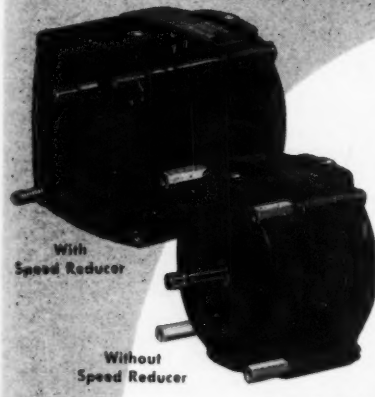
for Your Instruments



Bodine Type K motors, with or without speed reducer, are the heart of many precision instruments. Accurate, dependable, trouble-free, Bodine motors provide continuous day-in-day-out operation of your quality instruments.

The Bodine Type K motor, of superior design, workmanship, and performance, is a highly dependable source of compact power. Only 2⅜" high, it provides from 1/2000 to 1/500 horsepower, with reducer speeds down to 1 rpm. Write, today, for information. Bodine Electric Co., 2244 W. Ohio St., Chicago 12, Illinois.

BODINE

FRACTIONAL HORSEPOWER MOTORS

provided with stands which house electrical controls.—*Tinius Olsen Testing Machine Co., Easton Road, Willow Grove, Pa.*

Mention No. 348 when filling out card.

Unbreakable Hydrometer

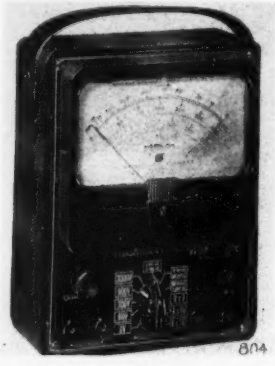
New pencil-sized hydrometer for measuring gravity of mold or core coating materials is 7.75 in. long, may be carried in pocket like a pencil. Body

is of a clear plastic, enclosing easy-to-read 0 to 70 Beaume' scale for heavier-than-water materials such as paints, slurries and liquids containing solids. —*Harry W. Dietert Co. 9330 Roselawn Ave., Detroit 4, Mich.*

Mention No. 349 when filling out card.

Multi-range Electrical Tester

New "Model 104 Volometer" weighs 2 lbs. 5 oz., is housed in a high-impact round-cornered Bakelite case with carrying strap, and has dim. 5.25 by 6.75 by 2.88 in. Instrument covers 5 d-c.

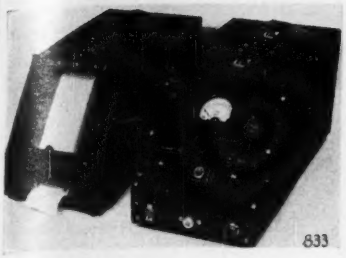


voltage ranges at 20,000 ohms per volt to 3,000 v., 5 a-c. voltage ranges to 3,000 v., 3 resistance ranges to 20 megs., and 3 a-c. & d-c. current ranges to 5 db ranges.—*Electronic Measurements Corp., 423 Broome St., New York 13, N. Y.*

Mention No. 350 when filling out card.

Direct-inking Oscillograph

New oscillographic equipment provides instantaneous recording on strip chart at frequencies up to 120 cps.; instrument includes amplifier and single- or double-channel recorder.

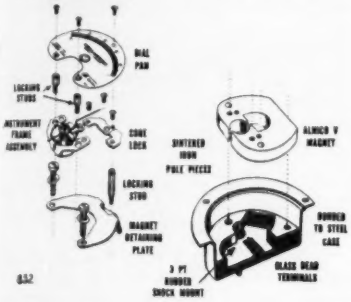


However, amplifier or recorder may be used separately. Chart speed is variable. A small plexiglass door on front of instrument gives access to chart for making notations. Front of case is hinged for ease in replacing chart paper rolls.—*Photron Instrument Co.*, 6516 *Detroit Ave., Cleveland 2, Ohio.*

Mention No. 351 when filling out card.

Electrical Indicating Instruments

New "Ruggedized" line of d'Arsonval-type d-c. movement instruments is designed to withstand such tests as tumbling in a barrel for one hour,

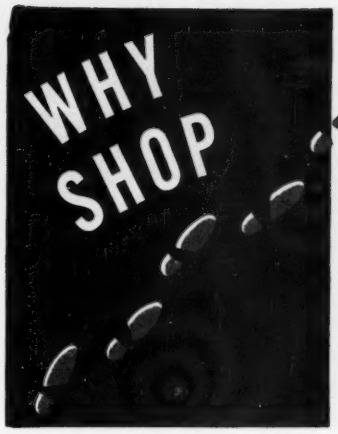


heavy vibration for six hours, and 2,000 foot-pound blows to panel on which instrument is mounted in each of three orientations. Instruments are hermetically sealed; are lighter in weight than former models.—*Marion Electrical Instrument Co., Manchester, N. H.*

Mention No. 352 when filling out card.

TV Volt-ohmmeter

New vacuum-tube volt-ohmmeter has d-c. voltage ranges of 0 to 3- 10- 30- 100- 300- and 1000 at an input resistance of 11 megohms, and 0 to 30 kv. at 1100 megohms; a-c. voltage ranges of 0 to 10- 30- 100- 300- and



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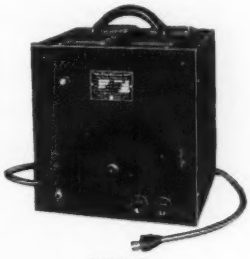
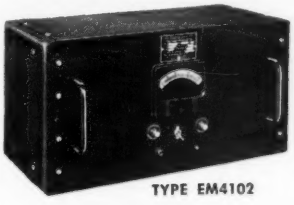
If you're looking for dependable automatic voltage regulation, investigate STABILINE first. You'll save time and money — you'll get longer service through better design and construction — you'll get performance and operating characteristics as advertised.

AVAILABLE IN 2 TYPES

STABILINE Type IE is instantaneous and completely electronic in action. Keeps output voltage to within ±0.1% of preset value regardless of wide line variations; to within ±0.15% regardless of load current or power factor changes. Waveform distortion *never* exceeds 3%. STABILINE Type IE is available in cabinet or rack mounting models — in numerous ratings.



TYPE IE
PORTABLE



TYPE EM4102

STABILINE Type EM (Electromechanical) features zero waveform distortion, insensitivity to magnitude and power factor of load, no effect on system power factor; no critical adjustments. It is available in output ratings up to 100 KVA — for single and for 3 phase operation.

STABILINE Types IE and EM perform "as advertised". Each and every STABILINE Automatic Voltage Regulator is inspected and tested to the most rigid specifications. If — after you purchase a model of either type — you would like a copy of the inspection and test report, write us and a full report will be sent promptly.

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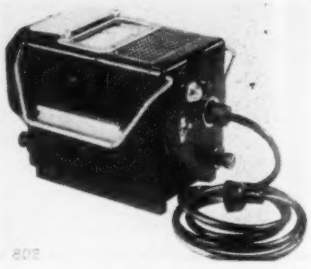
1000 at 1000 ohms per volt; resistance ranges of 0 to 1- 10- and 100 kilohms and 0 to 1- 10- and 1000 megohms; and has R.F. voltage ranges of 0 to 3- 10- 30- 50 useful to over 100 megacycles. Operation is from 110-120 50-60 cps. current.—*Transvision Inc., New Rochelle, N. Y.*

Mention No. 353 when filling out card.

Production-line Insulation Tester

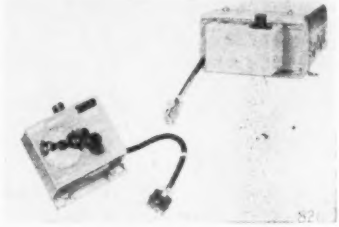
New rectifier-operated type of "Megger" insulation tester contains a power-pack consisting of a constant-voltage step-up transformer and selenium rectifier, giving a constant d-c. test voltage. Instrument covers a wide range and is independent of supply voltage.—*James G. Biddle Co.*, 1316 *Arch St., Philadelphia* 7, *Pa.*



Mention No. 354 when filling out card.

Aircraft Navigation Radio Receiver

New "Model LR-5BR" receiver features continuous tuning for all VHF-tower, radio-range and VOR-reception facilities. Receiver weighs 3 lbs. 11 oz. and measures 3.5 by 6.44 by 10.85 in.



Control unit, "Model LR5-CR," for receiver weighs 6 oz.; dimensions are 1.88 by 3.91 by 3.79 in.—*Aircraft Radio Div., Lear, Inc.*, 110 *Ionia Ave..N. W., Grand Rapids* 2, *Mich.*

Mention No. 355 when filling out card.

D-c. Power Supply

New "6RS10" 6-volt portable d-c. power supply is continuously variable from 0 to 8 v. Unit may be operated continuously at 10 amp. and intermittently at 20 amp. with less than 1.0 v. ripple. Supply is equipped with a 0-20 d-c. ammeter, a 0-10 d-c. voltmeter, a self-resetting circuit breaker in d-c. line, and a switch and fuse in a-c. line. —*P. R. Mallory & Co., Inc.*, 3029 *E. Washington St., Indianapolis* 6, *Ind.*

Mention No. 356 when filling out card.

Insulation Tester

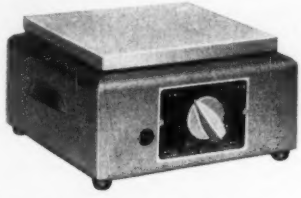
New insulation tester consists primarily of a high-voltage transformer, a motor-driven auto-transformer, an indicating voltmeter, and mercury cups or terminals for connecting specimens. Two models are available; one rated at 35 kv., 5 kva.; the other at 12 kv., 0.5 kva. Cabinet dimensions are 20 by

16 by 35 in. Overall weight is approx. 300 lb. Standard rate of rise of secondary voltage is 500 per sec. At breakdown of specimen insulation, an overcurrent relay operates to stop motor-driving mechanism and to open primary, de-energizing circuit. Voltmeter has a linear scale and will remain fixed at breakdown voltage until mechanism is reset to zero. Instrument can be used for fatigue testing. Automatic timer records actual test time that specimen is under stress.—*Westinghouse Electric Corp., Box* 2099, *Pittsburgh* 30, *Pa.*

Mention No. 357 when filling out card.

Electric Hot Plate

New "Temco" Electric hot plate has thermostat which provides control from 100 to 700 F. Temperature variation is held within 5 at 100 F.



and within 2 from 200 F. to max. A neon indicating light glows while plate is heating. Cast-aluminum surface plate is 6 by 6 in. Weight is 4.5 lb.—*Thermo Electric Mfg. Co.* 496 *W. Locust Street, Dubuque, Iowa.*

Mention No. 358 when filling out card.

Wiring Terminal Lugs

New line of miniature terminal lugs has been designed and engineered to meet requirements of component-parts trend toward smaller size equipment throughout electronic industry.

Elapsed time intervals can be measured down to 1/1000th second with a

STANDARD PRECISION TIMER

The world's most accurate (and rugged) time measuring instrument. Available in 8 models as shown below:

MODEL	READS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	± .1 sec.
S-60	1/5 sec.	60 min.	± .1 sec.
SM-60	1/100 min.	60 min.	± .002 min.
S-10	1/10 sec.	1000 sec.	± .02 sec.
S-6	1/1000 min.	10 min.	± .0002 min.
S-1	1/100 sec.	60 sec.	± .01 sec.
MST	1/1000 sec.	.360 sec.	± .001 sec.
MST-500	1/1000 sec.	30 sec.	± .002 sec.

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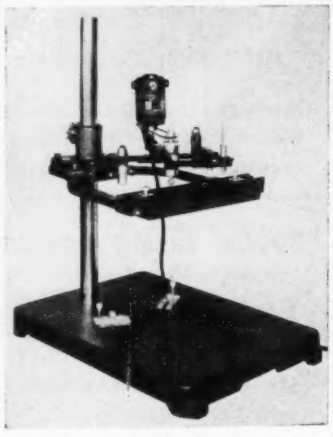
MICO ENGRAVER
Model 253



A further adaptation of the already proven Mico Engraver, Model 252. Will perform accurate engraving on panels 19-inches wide and of unlimited length. Accommodates work up to 19-inches high.

Catalog on request

MICO INSTRUMENT CO.
86A Trowbridge Street
Cambridge 38, Mass.

Lugs are silver plated and specially treated to prevent corrosion. All undergo rigid inspection to maintain tolerances.—*U. S. Engineering Co., 521 Commercial St., Glendale 3, Calif.*

Mention No. 359 when filling out card.

High-vacuum Diffusion Pump

New "MCF—300" fractionating oil-diffusion pump provides a speed of approx. 300 liters per sec. in range 0.01 to 1 micron Hg, the highest ever achieved with a 4-in. I.D. pump casing. An ultimate vacuum of 0.0005 micron Hg at 25 C. is attainable without cold traps. With Octoil as pump fluid, unit will operate against a forepressure of 0.150 mm. Hg or more, depending on heater input.—*Distillation Products, Inc., 755 Ridge Road West, Rochester 13, N. Y.*

Mention No. 360 when filling out card.

Small-size Silver-type Storage Battery

New "Silvercel" storage batteries, available in five types from 0.5 to 40 amp.-hour capacity require one-third to one-half the volume, and have one-fifth to one-third the weight of lead batteries of same capacity. Cells are leakproof,

and give off no fume or spray. Life is longer than for lead cells, and compares with ferro-nickel or cadmium-nickel batteries. Discharge curves are essentially flat with no damage from heavy overloads.—*Yardney Electric Corp., 105-107 Chambers St., New York 7, N. Y.*

Mention No. 361 when filling out card.

TV Components

New television components with instrumentation applications are announced:

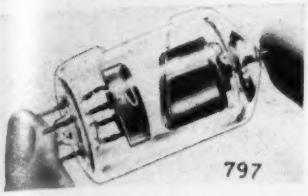
(1) 16GP4, 16 in. "Metal" picture tube.
(2) 206D1, Deflecting yoke.
(3) 208R1, Width control.
(4) 209R1, Horizontal linearity control.
(5) 218T1, Horizontal-deflection output and high-voltage transformer.
(6) 222T1, Vertical-deflection output transformer.

—*Tube Dep't., Radio Corp. of America, Harrison, N. J.*

Mention No. 362 when filling out card.

"World's Smallest" X-ray Tube

New "Mini-X 045A," said to be the world's smallest x-ray tube, was developed for dental radiography but will find industrial applications. Length 2.5



in. including pins; dia. 1.125 in. Tube has an extremely small and critical focal spot of 0.8 sq. mm. (conventional x-ray tube focal spots vary from 1.5 to 2.1 sq. mm.); it has a stabilized amount of radiation output and its radiation is more concentrated, thus producing higher contrast and greater definition in x-ray picture. It is of stationary-anode type for oil-immersed operation; operates at 45kv. and 7 ma. —*Amperex Electronic Corp., 25 Washington St., Brooklyn 1, N. Y.*

Mention No. 363 when filling out card.

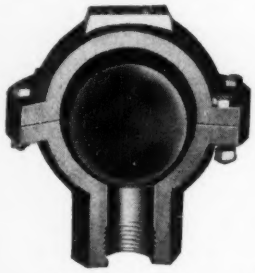
Hermetically-sealed Photocell

New hermetically-sealed selenium photocell has an average current sensitivity of 600 microamperes at illumination of 100 foot-candles with 100-ohm external circuit resistance. Assembly features extruded brass case using a glass-to-metal sealing alloy. Space utilization factor of unit is high as case measures 2 in. square by 0.437 in. thick; active cell area approx. 2.25 sq. in. Positive contact is made by a center lug and negative terminal lug is 0.75 in. away from positive one. Two insulated mounting screws are located 0.5 in on either side of positive contacts.—*International Rectifier Corp., 6809 So. Victoria Ave., Los Angeles 43, Calif.*

Mention No. 364 when filling out card.

Pipe-line Shock Absorber

New "Heyden" pipe-line shock absorber consists of a rubber cushion, encased in a spherical-metal chamber, which pulsates according to system



pressure. Three models, of different capacities, are available for industrial use. One model has been tested up to 3600 lb. continuous duty. Absorbers may be installed in any position.—*R-S Products Corp., 4530 Germantown Ave., Philadelphia 44, Pa.*

Mention No. 365 when filling out card.

Resistor Assortments

New assortments of 510 to 2025 resistors to cover the complete RMA range are available in 0.5., 1, and 2-watt sizes with 5 or 10 percent tolerances. The eight types of assortments offered

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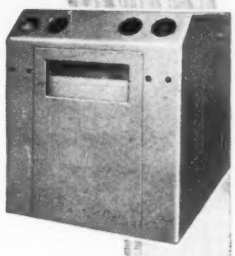

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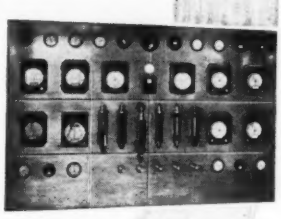

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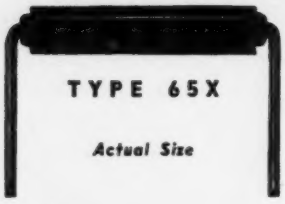

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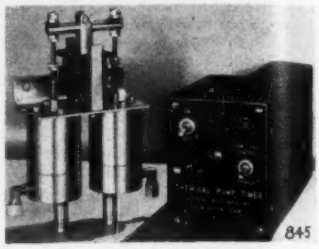
Metering Pump

New "Electronically Controlled Metering Pump" for remote-control applications is operated by an electronically-controlled solenoid providing variable control of number of strokes per unit time. Additional adjustment of length



of stroke is available to a maximum output of 0.8 cu. in. per stroke. Mechanical sealing arrangement is said to eliminate stuffing-box adjustments and periodic maintenance. Electronic timer is said to be built to run continuously for years with no replacements. Overall sizes: timer approx. 9.75 x 4 x 5 in. high, pump 6.5 x 4.5 x 2.62 deep.—*Eastern Industries Inc., 296 Elm St., New Haven* 6, *Conn.*

Mention No. 367 when filling out card.

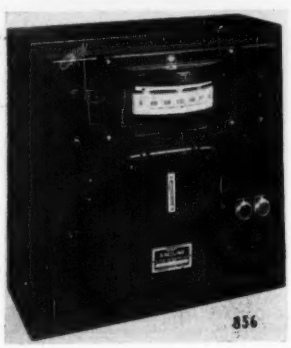
High-vacuum Diffusion Pump

New "MCF-60" diffusion pump provides a speed of 60 liters per second in the range 0.01 to 1 micron Hg, and an ultimate vacuum of 0.0005 micron. It embodies a 3-stage concentric-cylinder type of fractionating jet assembly fitted into an enlarged boiler. When Octoil is used, vapor jets will operate against a forepressure of 0.2 mm. or more—depending on heater input. Water-cooled casing is provided with an external heating unit. Jet assembly can easily be removed for cleaning and there are no fixed compartments in boiler.—*Distillation Products Industries, Rochester* 3, *N. Y.*

Mention No. 368 when filling out card.

Enclosed Instrument Panels

New enclosed panels, complete with pilot light and push-button station, are wired and ready for connecting power and TC leads to terminals in panel.

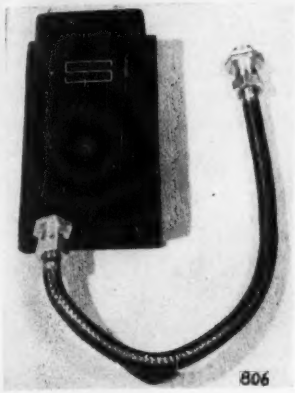


Available in two sizes: 19 by 15 by 7 in.; and 21 by 21 by 9 in., panels are made of 16-gage steel finished in black-baked enamel.—*Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.*

Mention No. 369 when filling out card.

Photoelectric Pickup

New photoelectric pickup, designed for industrial service where space is at a premium, has dimensions of 6 by 3.5 by 1.75 in. It is housed in a cast-aluminum case and is made in a variety of

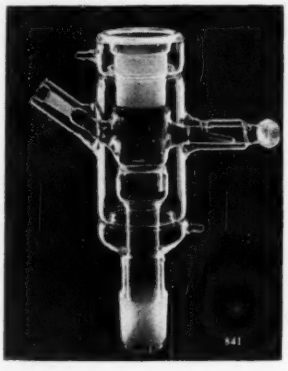


models to suit special installations. Since amplifier tube is in same housing as phototube, no coaxial or shielded cable is necessary.—*Ess Instrument Co., 96 S. Washington Ave., Bergenfield, N. J.*

Mention No. 370 when filling out card.

Feed Section for Fractionating Column

New redesigned "Glenlab" feed sections for laboratory fractionating columns have additional temperature-measuring facilities. A well accommodates a 3-in. immersion thermometer or thermocouple directly in rising vapor stream; a second thermocouple well is



located in the input-connector projection and positioned for intimate contact with the fluid even at minimal flow-rates. Other features of new feed sections for 1-in. and 2-in. columns are thermal-insulating jackets (as illustrated) with high vacuum pumped at high temperatures; an observation window in jacket silvering for measurement of liquid return; temperature-compensating bellows to permit opera-

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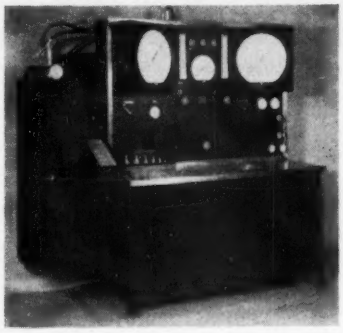

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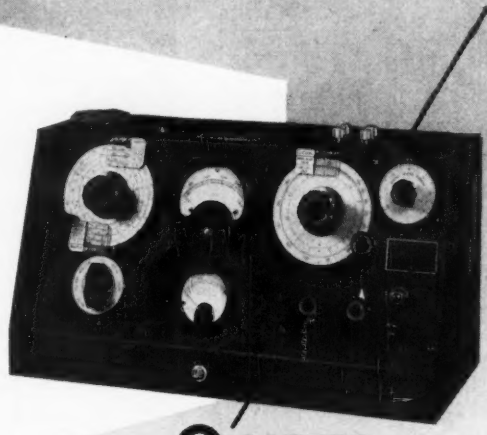

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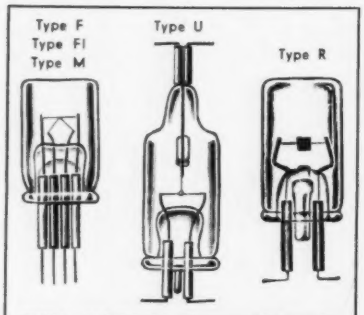

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tion up to 500 F. and of internal-convolution design to minimize possibilities of mechanical damage.—*Glass Engineering Labs.*, 609 *O'Neill Avenue, Belmont, Calif.*

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Proportional-counter Converter

New "Model PCC-10 Proportional Counter Converter" converts any standard scaler, with a suitable high-voltage supply, to a proportional counter. It consists of a counting chamber, amplifier, pulse height selector, high-voltage connector, leakproof bubbler, and low-voltage plug and cable. Counting chamber's unique design permits counting of such sample types as evaporated salts, precipitates, compressed pellets, and ashed samples. All samples are counted with 2π geometry. Decontamination

requires only ten minutes for complete takedown, cleaning, and reassembly. Performance feature is unusual effectiveness for counting soft betas: counter is windowless and no absorption of energy loss occurs, even the lowest energy rays are counted with full efficiency. This feature permits short half-life isotopes to be followed for about 6 half-lives further than with GM tubes. New instrument will at one time count alphas in presence of betas and then, by raising voltage, count betas in presence of the alphas. Alpha plateau extends from 1000 to 1300 v. and beta plateau extends from 1600 to 1900 v.; tilt of either is less than 2 percent per 100 v. average, with best 100 v. having a tilt of less than 0.5 percent. Power requirements: 300 vdc. at 20 ma.; regulated 150 vdc. at 6 ma.; 6.3 vac. at 1.4 amp.; regulated high-voltage supply variable from 800 v to 2000 v.—*Nuclear Measurements Corp.*, 3339 *Ceniral Ave., Indianapolis, 5, Ind.*

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Miniature Batteries

New "RM-1" mercury battery is 0.625 in. dia., 0.644 in. high, weighs 0.39 oz. and has a capacity of 1000 ma. hours. Complete line now includes batteries with capacities from 1000 to 3600 ma. hours, individual cells ranging from 300 to 3200 ma. hours and stack assemblies in a wide variety of sizes and capacities.—*Battery Div., P. R. Mallory & Co., Inc., North Tarrytown, N. Y.*

Mention No. 373 when filling out card.

Radioactivity Demonstrator

New "Model 1613" demonstrator consists of basic counting instrument which gives a visible neon-tube flash and an audible click indicating each disintegration. Milliameter shows amount of radioactivity. Twenty-eight

page manual explains graphically how to use accessories which are included in complete setup: two sources of radioactivity; a set of lead, aluminum and paper absorbers; and a calibrated mounting device for fixing positions of accessories.—*Nuclear Instrument and Chemical Corp.*, 223 *W. Erie St., Chicago* 10, *Ill.*

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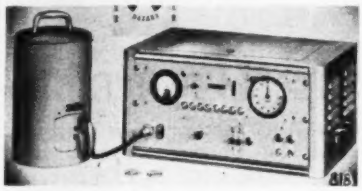
Radioactivity Scaler

New "RCL Scaler" uses Higinbotham scale-of-two circuit for scaling up to 64, 128, 256, or 512 before counting on register. Voltage-supply range is 500-2000 v., regulated to give less than 0.1



percent change for 10 percent line-voltage variation. Sensitivity is variable from 0.25 to 5 v., and resolving time is less than 5 microseconds. Electric timer is built in.—*Radiation Counter Labs., Inc.*, 1844 *W. 21st St., Chicago* 8 *Ill.*

Mention No. 375 when filling out card.

AD CORRECTION

In our Dec. 1949 issue, page 1131, the street number in the address of the Weller Mfg. Co. ad appeared upside down. It should read: 800 Packer St., Easton, Pa.

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CONTENTS

EDITOR'S FOREWORD

AUTHOR'S PREFACE

CHAPTER I—ESSENTIAL TOOLS

CHAPTER II—D-C. INSTRUMENTS

Dismounting and Reassembling, 5—KX-124 Instruments, 5—DB-12 Instruments, 11—Test and Inspection, 12—Principles of Operation, 19—Maintenance, 20—Connections, 22.

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CHAPTER III—A-C. AMMETERS AND VOLTMETERS

Principles of Operation, 24—Construction, 25—Dismantling KA-24 Instrument, 28—Reassembling, 33—Dismantling DB-12 Instrument, 34—Test and Inspection, 35—Internal and External Connections, 36—Maintenance, 36.

CHAPTER IV—ELECTRODYNAMIC TYPE INSTRUMENTS

WATTMETERS, 39—Construction, 39—The KF-24 Wattmeter, 39—The AB-12 Wattmeters, 48—Connections, 49—Principle of Operating, 49—Inspection and Calibration, 51—Single-phase Wattmeter, 52—Poly-phase Wattmeter, 53—Maintenance, 53.

FREQUENCY METERS, 56—Construction, 56—The KF-24 Instrument, 56—The AB-12 Instrument, 60—Principles of Operation, 61—Test and Inspection, 63—Maintenance, 66.

CHAPTER V—POWER FACTOR METERS AND SYNCHROSCOPES

POWER FACTOR METERS, 67—General Description, 67—Dismounting and Reassembling, 69—Inspection and Calibration, 74—Maintenance, 77.

SYNCHROSCOPES, 81—Description, 81—Inspection and Test, 83—Maintenance, 85.

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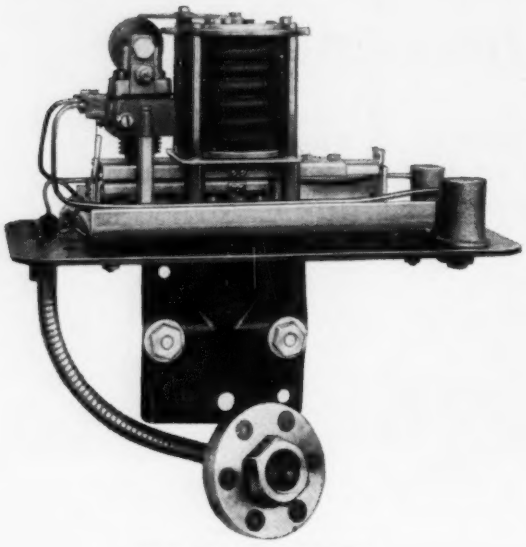

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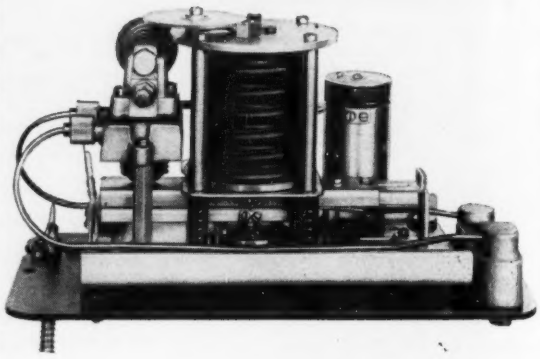
7. Interchangeable manifold assemblies make 20 and 40 psi range spans optional.

*Trade Mark



TEMPERATURE:

New Taylor TRANSAIRE Temperature Transmitter with Speed-Act* lets you measure and transmit smallest temperature changes up to 1000 feet with instant accuracy! The *only* temperature transmitter that gives you:

1. DYNAMIC ACCURACY—which means the accuracy of an instrument in measuring changing or dynamic conditions. Transaire Dynamic Accuracy is unparalleled. Solves the problem of process engineers who realize that an instrument accurate to a fraction of a degree in measuring static condition can be in error by many degrees when temperature is changing.

2. DYNAMIC COMPENSATION—which means ability to compensate for inherent lags both in measuring system and rate of heat transfer of process medium. Transaire does this by introducing derivative action (Speed-Act) into the *measuring* circuit. The result is Dynamic Accuracy, with a speed of response seldom thought possible which permits much closer automatic temperature control.

▼ ▼ ▼

For complete details, write for **Bulletin 98140** on TRANSAIRE Temperature Transmitter, and **Bulletin 98099** for TRANSAIRE Pressure Transmitter. Ask your Taylor Field Engineer! Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada.

TAYLOR INSTRUMENTS MEAN ACCURACY FIRST

JOURNAL of the Instrument Society of America

I.S.A. National Office, 921 Ridge Ave., Pittsburgh 12, Penna.

Vol. 6 MARCH 1950 No. 3

ISA FINANCIAL STATEMENTS FOR FISCAL YEAR 1949

Mr. Hugh E. Ferguson,
National Treasurer,
The Instrument Society of America
921 Ridge Avenue
Pittsburgh 12, Pa.

Dear Sir:

I have examined the books, records and accounts of the Society for the calendar year 1949, compared the records of cash received and disbursed with the statements of its depositories, reconciled the balances therein with the amounts shown in the statements submitted herewith and without making a detailed audit have examined or tested the transactions to the extent deemed appropriate in the circumstances.

A statement of condition, and operating results are presented in exhibits designated as follows:

Statement of Condition, December 31, 1948

Summary Statement of Income and Expenses for Calendar years 1949 and 1948.

Statement of Income, in detail for Calendar year 1949 and 1948.

Statement of Expense, in detail for calendar years 1949 and 1948.

Statement of Membership Receipts and Refunds for Calendar year 1949.

In all detailed Statements the account number precedes the account title.

These statements reflect actual cash receipts and disbursements during the period under examination. Your attention is directed to the report which follows, together with comments thereon.

Respectfully submitted,
J. A. HOLLINGSWORTH
Certified Public Accountant

STATEMENT OF CONDITION

The cash was on deposit in the banks listed in this statement. The aggregate cash balance was $34,995.31 at December 31, 1949. Recorded receipts were traced to the several depositories. Disbursements were supported by checks signed by the proper officers. The cancelled checks were inspected during the course of this examination.

It was noted that a number of small expenditures were made for the account of the Society by Mr. Richard Rimbach personally, he later being reimbursed by the Society. The Executive Committee might give consideration to establishing an appropriate "Petty Cash Fund" for the purpose of meeting on-the-spot payments of an approved nature.

The Society purchased $10,000.00 Par Value U. S. Treasury Bonds, Series G. The bonds are dated September 1, 1949, are registered in the name of the Society and bear interest at rate of 2½% payable in semiannual installments.

The statement shows prepayments and receivables of $853.00. This is composed of $30.00 in returned or "N. S. F." checks and $823.00 for January 1950 salaries for which checks had been prepared and recorded.

Because of the need of forwarding checks to the Treasurer for signature it has become the practice to prepare and record salary checks in advance of the pay periods. The Executive Committee might consider the establishing of a payroll account at a selected bank, depositing therein a sufficient working sum for the purpose of meeting weekly payroll requirements subject to check on one signature; funds drawn from this account to be replaced by regular Society checks supported by approved payrolls.

The recorded liabilities of the Society were with held income taxes from employees of $379.90 payable to the Collector of Internal Revenue.

The surplus at December 31, 1949 amounted to $45,468.41. This however is subject to reduction in the amount of $1,182.50, being membership refunds on dues received in 1949. The refunds were made in January 1950.

The Surplus is $16,549.36 greater than at December 31, 1948. The increase is the result of financial activities of the Society during 1949 as reflected in Statement of Income and Expenses submitted herewith.

Your attention is invited to the statement of Membership Receipts and Refunds. It is noted that the practice of receiving and refunding of dues is not uniform. Some Sections pay gross dues to the Society and receive refunds of one-half while others remit only that portion of the dues to be retained by the Society. Because of this procedure the statement reflects variances between the ratios or receipts and refunds among Sections. It is recommended that a uniform procedure be established.

Statement of Condition, December 31, 1949

ASSETS

Cash in banks:		
Live Stock National Bank, Chicago	$ 207.14	
Bank of Nova Scotia	1,631.55	
West End Bank, Pittsburgh	1,300.57*	
Farmers Deposit National Bank, Pittsburgh	34,457.19	
		$ 34,995.31
Investments		
U. S. Treasury Bonds Series G		10,000.00
Prepayments and Receivables		853.00
TOTAL ASSETS		$ 45,848.31

LIABILITIES AND SURPLUS

Employees Withheld Taxes	$ 379.90
Surplus	45,468.41
Total Liabilities and Surplus	$ 45,848.31

*Overdrawn

Summary Statements of Income and Expense for Years Indicated

INCOME (See Exhibit I attached)	1948	1949
200 Memberships	$ 29,355.52	$ 35,619.17
400 Registration	6,307.78	6,145.47
600 Exhibits	52,838.14	55,953.04
1000 Administration	911.69	1,063.20
TOTAL INCOME	$ 89,413.13	$ 98,780.88
EXPENSE (See Exhibit II attached)		
100 Memberships	$ 26,011.14	$ 27,870.55
300 Meetings and Conferences	11,806.58	9,703.36
500 Exhibits	22,474.97	18,374.84
700 National Headquarters	10,537.01	21,370.26
900 Administration	6,263.15	5,292.41
TOTAL EXPENSE	$ 77,092.85	$ 82,611.42
EXCESS OF INCOME	$ 12,320.28	$ 16,169.46

Exhibit I—Statement of Income for Years Indicated

MEMBERSHIP	1948	1949
200 Charter fees	$ 50.00	$ 80.00
201 Membership dues (See Exhibit III attached)	28,127.75	34,897.00
204 Services to members	517.27	195.36
207 Buttons, banners, etc.	660.50	327.31
220 Binders and Recommended Practices		119.50
Totals	$ 29,355.52	$ 35,619.17
REGISTRATION		
400 Registration fees	$ 1,090.00	$ 551.00
401 Contributions toward meeting expense		11.94
408 Sale of Trans. to Non-Members		5.00
409 Sale of Tech. Preprints	1,523.72	1,401.67

448	Sale of Lunch & Dinner Tickets	3,657.40	4,164.86
449	Sale of Plant Trip Tickets		11.00
450	Registration fees, Sectional Meetings	36.66	
	Totals	$ 6,307.78	$ 6,145.47
	EXHIBIT		
605	Exhibit Space	$ 52,838.14	$ 55,871.20
612	Registration Record		10.00
695	Film Slide Space		50.00
699	Miscellaneous		21.84
	Totals	$ 52,838.14	$ 55,953.04
	ADMINISTRATION		
1003	Instruments Publishing Co.	$ 911.69	$ 1,058.00
1099	Miscellaneous		5.20
	Totals	$ 911.69	$ 1,063.20
	TOTAL INCOME	$ 89,413.13	$ 98,780.88

Exhibit II, Statement of Expense for Years Indicated

		1948	1949
	MEMBERSHIP		
100	Refunds to Individuals	$	$ 31.50
101	Refunds to Sections	14,366.25	15,773.50
102	Maintenance of Membership Records	342.31	783.53
103	Membership Promotion, General	571.53	448.44
104	Membership Promotion, Specific	44.77	572.07
105	Subscriptions to Instruments Magazine	5,089.14	5,556.00
106	ISA proceedings or Transactions	202.28	2,728.00
107	Purchase of Insignia	2,225.37	52.93
108	Membership Activity Awards		77.20
120	Recommended Practice Binders	3,169.49	1,847.38
	TOTALS	$ 26,011.14	$ 27,870.55
	MEETINGS AND CONFERENCES		
300	Promotional Matters and Notices	$ 1,189.16	$ 443.84
301	Registration Material & Costs	323.83	
302	Program Preparation and Printing	822.67	2,232.60
303	Program Mailing		422.45
304	Rental of Meeting Hall	470.84	520.53
305	Meeting Accessories	1,062.24	359.11
306	Meeting Recording Cost	60.44	11.00
309	Preparation of Preprints	2,409.81	2,597.20
345	Refunds on unused Tickets		63.25
346	Expenses of Committee in Charge	240.71	147.50
347	Travel Allowance for Speakers	444.83	
348	Catering & Entertainment	4,653.10	2,701.09
349	Cost of Plant Trips		204.79
350	Printing & Mailing Promotionals	128.95	
	Totals	$ 11,806.58	$ 9,703.36
	EXHIBITS		
500	Preparation of Promotional Materials	$ 2,548.55	$ 1,441.19
501	Mailing & Distribution of Promotionals	795.33	368.32
502	Public Relations and Advertising		73.71
504	Directions & Bulletins to Exhibitors	386.80	
505	Rental of Exhibit Space	3,150.00	3,999.72
506	Services Related to Exhibit Space	549.50	
507	Exhibit Accessories	6,277.36	3,605.49
508	Exhibit Utility Costs		36.94
509	Printing & Mailing of Space Contracts	53.70	519.13
510	Registration Materials	2,136.57	1,818.40
511	Registration Labor	587.31	189.00
512	Registration Record Reproduction		330.00
513	Maintenance Clinic		36.25
514	Exhibit Committee & Staff Expenses	478.21	375.45
515	Executive Office Staff Salaries & Expenses	1,046.00	
516	Directory Design & Printing	653.43	779.25
519	Attendance Analysis Surveys	1,315.93	1,442.59
520	Acknowledgements	9.20	184.79
591	Special Attractions	188.50	
593	Travel Allowances, Speakers		130.00
594	Catering, Meals at Exhibit Location		916.34
595	Film Slide		590.00*
596	Society Promotion Space in Show	13.88	
597	Insurance, Protection, etc.	1,193.09	861.03
598	Refunds of Space Overpayments	491.61	676.49
599	Miscellaneous	600.00	.75
	Totals	$ 22,474.97	$ 18,374.84

*Self liquidating

	NATIONAL HEADQUARTERS		
701	Office Space Rent	$	$ 380.00
702	Office Space Facilities		4.34
703	Office Equipment	675.25	966.75
704	Stationery & Supplies	378.02	1,905.85
705	Postage, Mailing Express	2,100.71	4,250.88
706	Telephone & Telegrams	612.88	748.91
707	Repairs to Office Equipment	58.41	44.05
709	Subscriptions to Publications		32.00
710	Business Association Dues & Expenses		100.00
711	Executive Salaries		3,600.00
712	Non-Executive Salaries	5,868.77	8,843.72
713	Temporary Labor Costs		15.00
714	Insurance Premiums	168.66	9.75
715	Federal S.S. Taxes		73.83
716	Unemployment Taxes	649.31	350.91
717	Fidelity Bonds	25.00	25.00
799	Miscellaneous		19.27
	Totals	$ 10,537.01	$ 21,370.26
	ADMINISTRATION		
901	Preparation & Printing of Material	$ 91.15	$ 79.80
903	Editorial Work for Journal	934.99	735.88
904	Expense of Editorial Office	111.80	
920	Exhibit Expenses of Secretary	4,005.40	189.00
921	Administration Expenses of Secretary		3,732.73
930	Expenses of Executive Committee	7.25	
940	Board of Directors Expenses	189.70	
951	Expenses of Employment Committee	69.25	
953	Expenses of Recommended Practices	135.72	35.11
954	Expenses of S. & M. Committee	142.40	27.00
960	Expenses of President's Office	237.59	185.00
980	Expenses of Treasurer's Office	35.00	7.89
981	Sundry	202.90	
990	Legal	100.00	
991	Auditing Expenses		300.00
	Totals	$ 6,263.15	$ 5,292.41
	TOTAL EXPENSE	$ 77,092.85	$ 82,611.42

Exhibit III, Statement of Membership Receipts and Refunds for Calendar Year 1949

SECTION	RECEIPTS	REFUNDS*
At Large	$ 279.00	$
Akron	255.00	105.00
Albuquerque	385.00	192.50
Aruba	340.00	40.00
Atlanta	130.00	77.50
Baltimore	707.00	328.50
Boston	640.00	140.00
California	1,547.00	850.00
Central Illinois	322.00	153.50
Central Indiana	499.00	239.50
Charleston	720.00	332.50
Chicago	2,564.00	1,290.50
China Lake	764.00	333.50
Cincinnati	680.00	340.00
Cleveland	1,234.00	592.00
Columbus	280.00	140.00
Cumberland	145.00	67.50
Detroit	726.00	298.00
Eastern New York	572.00	279.50
Gulf Coast	362.00	181.00
Houston	1,085.00	565.00
Kansas City	462.00	211.00
Louisville	379.00	210.50
Montreal	280.00	25.00
New Jersey	2,320.00	1,070.00
New Orleans	20.00	10.00
New York	2,107.00	1,016.00
Niagara Frontier	733.50	348.50
North Texas	311.50	92.50
Northern California	455.00	
Northern Indiana	140.00	65.00
Oak Ridge	680.00	340.00
Ontario	355.00	182.50
Philadelphia	3,392.00	1,646.00
Pittsburgh	1,814.00	907.00
Presque Isle	180.00	90.00
Richland	738.50	317.50
Rochester	690.00	350.00
St. Louis	1,301.00	598.00
Sarnia	449.00	8.50
South Bend	55.00	32.50
South Michigan	259.00	124.50
South Texas	430.00	197.50
Tennessee	345.00	182.50
Tulsa	787.00	392.50
Twin Cities	310.00	155.00
Washington	875.00	470.00
Wayne County	452.00	185.00
Wilmington	92.50	
Pittsburgh Inspection List	55.00	
Unidentified	193.00	
Totals	$ 34,897.00	$ 15,778.50

* Where the refund is less than half the amount received, these Sections collected dues and forwarded only half the dues to the National Office.

Refunds for dues collected in December 1948 are included in these figures. Refunds for dues collected in December 1949 are not included.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.

ELECTRONIC ENGINEER. Graduate with five years practical experience with Audio-Frequency design for permanent employment as Quality Control Engineer. Age limit 29 to 35. Salary $6000 per year range. Location Chicago. Box 281.

• • •

INSTRUMENT ENGINEERS (4) Select proper process control instruments for maintaining proper conditions of temperature, pressure, flow, etc. Write specifications for obtaining bids, analyze bids, and select proper suppliers. Layout arrangement of instruments. Requires knowledge of chemical process instruments and operations. Wide knowledge of type and makes of instruments and instrument control theory and application. B. S. Chemistry, Chemical Engineer or Mechanical Engineer desirable but not mandatory. Write giving complete resume of education and experience, when available and salary expected. Pittsburgh area. Box 282.

• • •

INSTRUMENT DRAFTSMEN (2) Minimum of three years experience on instrument panels, instrument piping and wiring diagrams pertaining to chemical process plants. Pittsburgh area. Box 283.

• • •

ASS'T CHIEF ENGINEER by midwest regulating valve manufacturer. Must be competent designer in valve and control instrument field with application knowledge. $6500 with bonus for outstanding performance. Location Chicago. Box 284.

1950
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W. A. WILDHACK

Instrumentation for Testing

Instrument Repairman Trade Apprentice Training Program*

By J. H. CUTHBERT†

APPRENTICE Training Programs have a place in the early history of steel making. Some forty-six years ago the South Works of Carnegie-Illinois Steel Corporation, then called the Illinois Steel Company, recognized the value and necessity of having an Apprentice Training Program and in 1903 the first Trade Apprentice Program was inaugurated. This was strictly an electrical course specializing in armature winding. During the early 20's the teaching of theory in the classroom was started with the apprentice spending about one-half day a week in the basement of the shop with an electrical instructor.

During the year of 1903 to 1935 the Training Programs were changed and improved, and additional trades and crafts were embraced. Following the merger of the Illinois Steel Company and the Carnegie Steel Company in 1935, training Bureaus were established to handle the details and problems of apprentice training. Regularly scheduled related instruction classes consisting of trade theory, mathematics and blueprint reading were included in the training. These classes were taught by instructors who were furnished by the plant and who had both a technical and practical background, and a concentrated effort was made to develop young men out of high school into skilled craftsmen.

During the past decade the magnitude of plant instrumentation was recognized by those in charge of training, and to cope with this fast developing specialized craft, the position of instrument repairman was included in the list of trade and craft positions, and, accordingly, a full-scale apprentice training program for this trade established. The instrument repairman in a modern steel mill is the jeweler of industrial craftsmen. The tools of his trade are precision instruments for testing equipment. He must be familiar with the functioning of various types of meters, gauges, timing devices, controls and pyrometric equipment. He must be able to analyze all types of instruments, drawings and wiring diagrams, and be able to dismantle, clean, inspect, repair and calibrate any of this equipment. He must be a skilled trouble shooter and have a thorough knowledge of the application and operation of instruments and controls.

The purpose of the training program is to develop and maintain in the plants of the corporation a complement of skilled instrument men adequate to maintain its facilities and equipment at a high degree of efficiency. To accomplish this purpose the trade education of a young man in apprenticeship is based on the following four objectives.

1. To develop skill in performing the duties of his trade.
2. To advance his technical knowledge in subjects related to the trade.
3. To impart an understanding of the problems of industrial management and the place of industry in the community.
4. To encourage continuing self-education and ambition toward advancement in the organization.

The number of apprentices in training in each plant is governed by the normal complement of the department, modified by such factors as labor turnover and apprentice turnover, anticipated terminations due to age, and the expansion or curtailment of the shop's activities.

All applicants for apprenticeship must be at least eighteen years of age. No maximum age limit is established. However, if an applicant is 25 years of age or over, each case is considered on an individual basis to insure that the applicant's financial obligations and responsibilities will permit him to live within the apprentice rate structure, and that the applicant is capable of learning all phases of the trade within the time limits established by the trade. Applicants for apprenticeship are also given an aptitude test. These tests are competitive, and those who show up best, everything considered, will be chosen. At the present time about 90% of our total enrollment are veterans.

All applicants must be high school or vocational school graduates, or the equivalent, and the character of each apprentice must be such as to insure that he is capable of assuming the responsibilities of journeyman status. An individual selected for apprenticeship must undergo a physical examination and meet the physical standards established by the plant physician for the particular trade.

As the introduction of instrument repairman trade apprentices was a new field for the steel industry, it became necessary to determine the extent and type of material to be used as related instruction in the classroom, and in view of this a committee of four men was appointed some two and a half years ago, consisting of three instrument department heads and a director of training who acted as chairman.

As the Carnegie-Illinois Steel Corporation plants in the East and Middle West used various types and makes of controls and instruments, the committee had a problem in deciding what material to use from available published books, what manufacturers' material was available, how the material was to be used, and how much of the material would be sufficient to give the apprentice enough basic facts and information so he would gain enough knowledge to become adept in all phases of instrument work. This related classroom instruction had to be set up to cover all the types of instruments and controls and still be flexible enough so that any individual plant not using a certain type of instrument or control could pass over part of the instruction and consider only the type of equipment pertinent to its own plant operations.

The committee has devoted one-half day a week for the past two and one half years to organizing and writing a course in trade theory and carrying out this training program. The course is broken down into four parts:

Part One covers the subject of pyrometry, including:

(a) Temperature Versus Heat
(b) The Thermocouple
(c) The Millivoltmeter
(d) Potentiometers
(e) Optical Pyrometers
(f) Radiation Pyrometers
(g) Resistance Thermometers
(h) Transition Points and Thermal Analysis

Part Two relates to flow and pressure measurement—including:

(a) Temperature, by glass thermometers, bulb type thermometers, mercury, gas filled and vapor-tension Systems, bimetallic strips
(b) Pressure and vacuum; covering Bourdon tube principles, helix principles, diaphram principle, oil seal systems and the theory and application of each.
All methods of
(c) flow measurement
(d) liquid level

Part Three is concerned with automatic control including:

(a) Electrical
(b) Hydraulic
(c) Pneumatic
(d) Mechanical

Part Four relates to electrical meters and instruments, divided into five parts as follows:

(a) A.C. & D.C. Indicating Instruments
(b) A.C. & D.C. Graphic or Recording Instruments
(c) A. C. & D.C. Watthour Meters
(d) Protective Devices or Relaying Equipment
(e) Switchboard Wiring

After the foregoing course was developed, including the reference material, each of the subjects was broken down into individual lessons, with four to twenty questions set up as an examination questionnaire. The reference material consists of various books covering all of the mentioned subjects, including manufacturers' material pertaining to some specialized line of instrumentation or control. Sufficient copies of this manufacturers' material have been secured for each apprentice.

The books are purchased by the training bureaus in each plant and resold to the apprentice at cost.

The schedule of hours for any apprentice is based on a forty-hour week, four of these hours being spent in school work for which he is paid his regular rate of pay. The 36 hours spent in the field are used to gain practical knowledge, dexterity, application and experience in the installation, maintenance, servicing and calibration of all instrumentation and controls,

Note:—Statements and opinions advanced in papers are to be understood as individual expressions of the authors and not those of the Society.

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Carnegie-Illinois Steel Corp., South Chicago, Ill.

broken down as follows: 12 months on pyrometric instruments and controls which includes 3 months on optical pyrometers, three months in the open hearths, three months in the mills on soaking pit temperature instruments and controls, reheating furnaces and plate temperature instruments, and three months in the blast furnace, heat treating and metallurgical departments. The apprentice will spend two years in the electrical section learning to repair, calibrate, install and test A.C. and D.C. watthour meters, graphic meters, indicating meters, switchboard wiring, power relaying equipment and the use of test equipment. During this two year period he will be given laboratory experience in checking sub-standards, testing base and Noble metal thermocouples, gauges, small control units, making parts and getting experience with new equipment brought in for acceptance tests.

The fourth year is broken down into three parts; three months on natural gas flow meters, three months on steam, water and oil flow meters, six months on combustion control equipment.

During the first two years of his training period, the classroom instruction is confined to basic instruction including "Practical Physics and Mechanics", "Shop Mathematics", "Mathematics for Electricians and Instrument Repairman", "Blue Print Reading and Drawing", "Advanced Blue Print Reading", "Making, Shaping and Treating of Steel", "Job Instruction Training", "Shop Economics", and "Trade Theory".

The second two-year period in the classroom is confined to advanced related instruction as previously outlined. It is believed that the student will better understand the complexity of instrument and control details at school if he has had some field experience.

During his four years of training the apprentice is rated periodically. One rating form is used by his immediate supervisor who observes him during his thirty-six hours of field work and rates him on his safety performance, attendance, care of company property, work quality, work quantity, personality, and ability to follow instructions. The classroom instructor rates him on his school work and observes his accuracy, conduct and industriousness, and grades him on the various units of related instruction.

An apprentice is required to be appraised "satisfactory" or better by his supervisor in the units of the schedule of shop practice on which he performed work or received instruction. An apprentice failing to maintain a satisfactory performance record during a period of apprenticeship remains in that period for 520 more hours of training, thereby increasing his total length of apprenticeship by 520 hours. During which time he receives specialized training in the type of work in which he failed.

In the final period and in order to be graduated from apprenticeship the requirements are:

1. The attainment of required grades in related instruction subject units for the trade.
2. The appraisal of full skill by shop supervisors in all basic factors of the Journeyman Classification Record for the trade.

In graduating the apprentice automatically becomes a starting rate Journeyman of the trade or craft, 1040 working hours later he becomes an intermediate Journeyman, and after completing another 1040 hours he becomes a top rate Journeyman.

An apprentice during his course of apprenticeship is expected to acquire as a minimum the tools necessary to maintain or repair equipment he may be assigned to work on. The plant will provide the apprentice with the privilege of purchasing these tools, charging him only the cost to the plant. Upon successful completion of the prescribed course of training for the trade or craft the apprentice receives an engraved and framed certificate of apprenticeship.

This and other trade apprenticeships are offered by Carnegie-Illinois Steel Corporation to assist the individual in becoming a well-trained tradesman capable of serving the equipment of production.

Instrument Mechanic Training*

By ROY JOHNSON†

THE design of an Instrument Training Course is guided by only one obligation — and that obligation is to create a training that will produce a graduate capable of performing the duties expected of him. Therefore, the preparation of such a course should be restricted by no academic traditions or artificial time schedules. The course should be designed to fulfill a specific purpose. The course may be short or it may be long, depending entirely on what is required in a particular field.

The reasons for setting up any training program are two-fold:

1. For men who need help in getting into new jobs in new fields of opportunity.
2. For industry which finds a lack of trained and experienced technicians in an ever expanding field.

The first area is the one in which I have been engaged for the past seven years and will be the basis for the suggestions to follow.

More often than not, men enrolling for vocational training are handicapped by a lack of formal education. For this reason, any man is accepted as a student when the Educational Director is satisfied that he is capable of assimilating successfully the training and of using profitably the knowledge and skills acquired therefrom. In general, any individual will be accepted for training who has completed at least two years of high school.

Individuals who have not completed elementary school will be accepted for training only when the Educational Director is satisfied that they have, through self-study, work experience, or otherwise acquired sufficient general education to permit them to complete satisfactorily, the training for which they have enrolled.

The training course must be thoroughly practical. The student spends a maximum amount of time actually servicing and overhauling the type of equipment being studied, and acquiring the necessary manual and analytical skills for performance on the job.

Of first consideration in the development of a training program is the preparation of training guides, designed to teach the overhaul, repair and calibration of instruments.

These materials must have three outstanding characteristics:

1. They must be flexible enough to be used under a wide variety of conditions,
2. They must be practical and useable for on-the-job reference, as well as for training purposes, and
3. They must be coordinated with manufacturers' manuals and recommendations.

To make any group of training guides fulfill such a set of conditions is not easy. It can be done, however, with proper advance planning.

The first step is to analyze, intelligently, the particular skills and knowledge that a man must have in order to be a competent instrument mechanic.

The second step is to analyze the various conditions under which the training will be given.

The third step is to design a training that will provide all essentials, under all training conditions.

The work of an Instrument Mechanic is a combination of manual skills and technical understanding. The particular knowledge required depends upon the degree of specialization. A man who is to work on pressure instruments only, must be taught a certain group of facts. One who is to work on electrical instruments must be taught another group of facts, for the most part wholly unrelated to those which the pressure instrument mechanic must know. Or, one who is to specialize on the overhaul of only one kind of electrical instrument can be given a more limited amount of information.

But, regardless of the degree of specialization, or of the particular type of instrument to be worked on, the mechanic must acquire certain fundamental skills that are common to all kinds of instrument work. It is true that an electrical instrument mechanic must possess certain skills not required of a pressure instrument mechanic. However, all must know the use of certain hand tools, be familiar with the

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Director of Training, Industrial Training Institute, Chicago 25, Illinois.

operation of the jewelers' lathe, bench lathe and drill presses, know how to repair pivots and bearings, be able to solder, to balance delicate parts and assemblies, and to perform a host of other operations common to all types of Instrument work.

In the final analysis, skill training is at least 75% of the job of making an Instrument Mechanic, whether he is to be a specialist or an all-round technician. Moreover, most of the skills to be taught are common to all types of instrument work.

It is obvious that the conditions under which Instrument Mechanics are trained in the various industries will vary widely. Even the methods employed for overhauling instruments differ in different industries.

At one instrument shop it is quite likely that the effort will be to train all-round instrument mechanics — mechanics who can work on all types of instruments.

At another instrument shop specialists may be produced by instrument class, as for example, mechanical, pressure, electrical, pyrometric, or flow mechanics. At still another instrument shop, specialization may be by instrument type and individuals taught only one particular type or model of instrument. And again, at another shop specialization may be by production line, overhaul methods, where one individual is taught the disassembly of a specific instrument; another, the overhaul and repair of a specific part; and a third, reassembly and calibration. Obviously, the method of training would vary with the type of specialization desired in any particular instrument shop.

Moreover, the method of training would be dependent on the needs and available facilities. At one instrument shop, the trainee may be taught as an individual by means of on-the-job instruction. In another instrument shop, a school may be established wherein individuals are taught in groups, in the classrooms, and in specially equipped training shops.

The competence of instructors would also affect the methods employed. One instrument shop may have competent and experienced instruction personnel. Another may have to rely on instrument shop foremen or experienced instrument mechanics to guide the trainee.

Equally important in determining the means to be employed in training, are the qualifications of the trainees themselves. One instrument shop with a well planned personnel selection program may select individuals well qualified for instrument work, whereas another may be training individuals with no previous experience and even with a limited amount of education.

In our 32-week training schedule, the particular method of approaching the problem which we suggest seems to us to be the one most likely to do the job.

This method was worked out in the course of our wartime training program. As the Chicago School of Aircraft Instruments we instructed approximately 75% of all service personnel trained in the study of aircraft instruments. In cooperation with the Armed Services a program of 4th echelon study in the overhaul and calibration of instruments was set up to feed air depots all over the world.

Our 3 year association with the Armed Services, under the pressure of wartime training, led to a streamlined program devoid of all frills and non-essentials.

We suggest that the training material be divided into series, covering the basic instrument classes, as follows:

1. Pressure Measurement Instruments
2. Flow Measurement Instruments
3. Electrical Measurement Instruments

We suggest this division because the most common form of specialization in instrument work is by instrument class. Further, it is a logical breakdown from an instructional point of view. Each class has principles of construction and operation which are generally common to all instruments within the class. Further, such specialized skills as must be acquired by the mechanic are generally applicable to all of the instruments within a class.

Moreover, arranging training guides into series, by instrument class, does not prevent the preparation of these guides in such a way as to permit more intensive specialization within a class if it is desired.

We should also like to suggest a series of training guides designed to acquaint the trainee with the tools and equipment all instrument mechanics must know and use and in so doing teach him the fundamental skills common to all types of instrument work.

This series of "Basic Shop" training guides would describe such things as: saws and sawing; drills and drilling; files and filing; taps, dies and thread making; operation of the jeweler's lathe; use of the staking arbor; soldering; use of hand tools; measurement and micrometers.

In these "Basic Shop" guides, a series of training projects are incorporated along with the description of each piece of equipment and its use, and the project so designed as to provide the trainee with experience in the use of the equipment in instrument work.

In our opinion, such a "Basic Shop" training should be one of the essentials of any training program designed to produce an instrument mechanic, regardless of the degree or the area in which that man is to specialize.

In normal instrument shop overhaul work the usual procedure is:

1. Pre-disassembly inspection of the instrument.
2. Disassembly.
3. Inspection of instrument parts.
4. Overhaul and repair of parts.
5. Reassembly.
6. Testing and calibration.
7. Installation.

This general procedure is approximately the same regardless of the instrument being worked on. Moreover, the specific overhaul procedures for any instrument in a group are approximately the same as for any other instrument within that group. Thus, if we teach a man the general overhaul procedures that are followed in repairing instruments of the various groups, and rely upon manufacturers' manuals to describe specific differences of procedure, we have produced a mechanic capable of overhauling *any* type of instrument, and have done it in little or no more time than would be required to produce a specialist on one instrument type only.

Our own experience in this type of teaching has been quite successful and we feel that it is by far the best approach to what heretofore has been a difficult problem.

Training guides provide a system of skilled training based on a series of projects using actual instruments as working material.

In training an Instrument Mechanic he would be given "Basic Shop" training, requiring him to perform the project assignments described in work guide sheets. This would take him approximately 100 hours, more or less, depending upon his previous related experiences and the equipment available in the shop.

Coincidental with his shop training, the student will study elementary physics, basic mathematics (arithmetic), and blueprint reading. This we find to be handled best through classroom meetings.

The use of film strips, motion pictures and other visual devices throughout the training pictorially demonstrates much more adequately than is possible by theory lectures alone.

Now, after this basic training the student is ready to begin his actual instrument training.

The training guide for a given type of instrument describes the general overhaul procedure for all the different parts that are found in instruments of that type. A man can take any one of the instruments in this group and find described in the training guide the procedures to be followed in overhauling every one of the parts of that instrument.

In conjunction with this overhaul and repair procedure, the student will be given classroom instruction in the principles of operation and the relationship of component parts.

In completing the training of the student, he will be given any one of the instruments of that group and placed at a shop bench with that instrument, his training guide, and required to disassemble and overhaul the instrument, following the procedures as set forth. With proper supervision he will go through the complete overhaul of any instrument of the same group.

Let us assume that the first instrument given the trainee is a Bourdon Actuated Steam Pressure Gauge. Upon completion of his project, he will have completely overhauled one Bourdon Gauge. If we're going to specialize this student on Bourdons alone, we would now have him go through the same procedure with another Bourdon, probably a vacuum gauge. Perhaps we would then have him go through the same procedure with a third Bourdon, a Compound Gauge, at which time he should be a fairly well trained mechanic on Bourdon Tube Gauges, capable of handling other types, such as vapor tension thermometers, mercoid controllers and warning units.

Our original thinking suggested that a teacher's manual should be prepared to go along with each training guide, which would contain complete instructions to the teacher and set forth lesson plans, examination questions, and other materials that the instructor could use in working with the student. We have found that there is no need for such instructor guides with this type of a training program. Actually, the training guides are so written as to permit their use by the student without the need of any instructor.

In practice, of course, an instructor

would and should be on hand to supervise the work of the student, but his efforts would be confined to supplementing, with his knowledge, the information contained in the training guides and to clarify any misunderstandings that might arise in the mind of the trainee. A measure of the student's assimilation of the material set forth in the training guides can very readily be seen in the quality of his completed work, and the result of examinations based on classroom theory and bench work.

One of the biggest advantages of this method of approach is the fact that it assures complete training in spite of any lack of previous experience on the part of the trainee. Almost any individual with experience in instrument work at all could serve as an instructor and do a satisfactory job.

Because we feel that this type of training must of necessity be skill training, 80% of a student's five hour day is spent at the bench, and one hour a day, or 20%, is spent in the classroom.

With classes held to a maximum of 15 to 18 students per instructor a four hour period at the bench permits rather close supervision. One hour spent in the classroom each day is ample time to present the theories and principles of operation.

Included in our pressure phase of training is a sensitive Aircraft Altimeter. Because we feel that the student should be familiar with an absolute pressure gauge, the altimeter was included in our course. We find, also, that because of its extreme sensitiveness and complexity of linkage, the altimeter serves admirably as an examination of the student's mechanical ability.

It is in the altimeter that the student first encounters jeweled bearings and is taught how to inspect them for flaws — and how to replace a jewel when necsary. The altimeter and its aneroid cell allows for the study of atmospheric pressure and its related pressure altitude. The altimeter provides unusual and desirable experiences.

In this pressure section or phase of training the student spends two hundred (200) hours studying the overhaul, repair, and calibration of pressure actuated instruments. Forty (40) hours of this time is spent in the classroom studying the theories and principles of operation of Bourdon Tube, Diaphragm, and Bellows Type Indicators, Recorders and Controllers. One hundred and sixty (160) hours of the student's time is spent at the bench actually working on the various types of instruments.

At the completion of this portion of the student's training, he should be familiar with the test equipment and procedures necessary for calibration. Deadweight testers, Comparator testers, Bell jars and Mercurial barometers, Pressure Pots and U-tube manometers and Pressure control panels are the pieces of test equipment studied and used during calibration.

The portion of our course devoted to the study of Flow Measurement requires that the student have a rather comprehensive knowledge of the nature of fluids. Therefore, considerable time is spent in the classroom explaining Bernoulli's and Venturi's theories.

By means of a flow line, through which compressed air is forced and regulated, it is possible to demonstrate the reaction in differential to a change in orifice size, or a change in total flow. By connecting Well Type Manometers to taps in the flow line, spaced at various pipe diameter intervals from the orifice face, we are also able to demonstrate the loss in static pressure due to friction in the line and to graphically illustrate pressure recovery. This flow panel also permits us to teach the square root function of the scale quite adequately.

We feel that the student should be given the opportunity to actually do some piping work and to make actual hook-ups from schematic drawings. If he is then permitted to disassemble, clean, inspect, overhaul, repair, and calibrate several types of flow meters he should be fairly well grounded in flow meter maintenance.

This phase of his training takes approximately one hundred (100) hours.

Because of the many desirable skills and techniques developed, we are still including in our present curriculum, the study of the directional gyro indicator. The overhaul, maintenance and calibration of this type of instrument is so subject to the utmost in accuracy and cleanliness that we feel that other types of instruments leave much to be desired in this direction. It is here that the student learns the use of precision drill presses for the purposes of lapping pivots, the use of specialized power equipment for the lapping of races, the use of surface plates and dial indicators for the purpose of exact centralization of parts, the development of a sense of feel to determine end-shakes and side-shakes to the thousandth of an inch, the technique of static and dynamic balancing, the use of various types of jig and holding fixtures, and the realization that each of the foregoing must be nigh on to perfect to insure the elimination of errors during calibration. In this phase the student learns skills which will stand him in good stead throughout his entire training.

This portion of his training will also take approximately one hundred (100) hours.

In our Electrical phase of training the student spends three hundred (300) hours in a rather all inclusive coverage of Electric Meters and Instruments, running the gamut from simple Galvanometers to the rather complex Pyrometer Potentiometers.

By means of Ohms Law problems and experimental circuit boards it is possible for the student to apply the knowledge he gained in classroom lectures to actual applications. Because it is so necessary for him to have a sound fundamental knowledge of electricity, considerable time is spent on the experimental circuit board developing his ability to trace a circuit, to recognize high resistance connections, line loss, and inherent meter error.

The first electrical instrument the student gets to work on is a simple D'Arsonval, moving-coil type Galvanometer. After studying the physical and electrical aspects of the meter, the student is taught the importance of sensitivity.

In learning about D. C. Voltmeters the student is required to re-range by using a decade box in series with the movement. Each student is also required to re-range D. C. Ammeters by means of "shunt" calibration. Standards, Wheatstone Bridges, Potentiometers, Decade Boxes, Multimeters, Ohm Meters, Magnet Chargers, and Magnet Agers are available for the student's use.

As an introduction to alternating current meters and instruments the student is taught the theory in the classroom by means of lectures and films, and on the bench, by means of experimental circuit boards.

The student further familiarizes himself with A. C. Theory and application when he overhauls and calibrates a Magnetic Drag Tachometer. The transmitter in this instance is an A. C. Generator. The Receiver is a Magnetic Drag Indicator whose cup is drawn up-scale in proportion to the Generator output.

The theory of Telemetering is discussed in the classroom and applied at the bench by overhauling and calibrating a 400 cycle transmitter and indicator.

In this portion of the Electrical phase the students also overhaul and calibrate A. C. Watthour meters.

The last portion of the Electrical phase is devoted to the study of Temperature Measurement.

Wheatstone Bridge principle Resistance Temperature Indicators and Resistance Temperature Indicators using a modified bridge ratio circuit are overhauled and calibrated by the student. When the student overhauls and calibrates a basic Millivoltmeter Temperature Indicator, the Millivolt-temperature relationship is extensively studied. At this time also, the student spends considerable time in the classroom learning Thermocouple Theory. He learns Thermocouple-fabrication, calibration, use, and application.

The natural sequence of events now leads the student into the study of the use, principle of operation, overhaul and calibration of Millivolt-temperature Recorders.

Investigation of the use and operation of the Optical Pyrometer is undertaken at this time. Comprehensive discussions and lectures on the theory of Potentiometer Circuits is given in the classroom. At the bench, the student learns the reason for, and the manner in which, standardization of the circuit takes place. He is also required to balance the Galvanometer and adjust the balancing mechanism so as to remove any stepping action of the pointer. He must trace and hook-up the control circuit to a laboratory furnace for actual operation. The student uses a portable Potentiometer for checking and calibration.

Because of the impossibility of teaching all types of instruments of all manufacture, we have been "hard-put" to find instruments of a given type which could be represented as basic and fundamental. We have tried to include in our curriculum at least two manufacturer's products which find greatest representation in the field. We are confident that upon completion of eight hundred (800) hours of such training, a student has developed sufficient mental and mechanical skills and ingenuity, that he can take his place in the instrument field and do a justifiable job for his employer and build for himself a future.

Men interested in doing work calling for a high degree of mechanical aptitude and manual skills will find training in instrumentation tremendously interesting and will also find in instrument work all of the satisfactions that every true craftsman seeks.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio.
Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.
March 28, "A Tour of The Fourth National Instrument Exhibit," Slide Film No. 1.
April 25, Slide Film No. 2.

ALBUQUERQUE
L. J. Paddison, 911 Parkland Circle, Albuquerque, N. M.
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
K. H. Walker, P. O. Box 389, c/o Lago Oil & Tranpsort Co., Ltd., Aruba, N.W.I.
First Tuesday, Meeting at 7:15 P. M.

ATLANTA
H. Benritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
George B. Greer, 631 E. 36th St., Baltimore 18, Md.
Second Friday.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La.
Meeting at 7:30 P.M., L.S.U. Geology Bldg.
April 3, "Gadgets," R. D. Webb, Carbide & Carbon Chemicals Corp.

BOSTON
C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., Patten's Restaurant.

CALIFORNIA
D. C. Duncan, Helipot Corp., Meridian Ave., S. Pasadena, Calif.
First Tuesday, Dinner at 6:30 P. M. Meeting at 8:00 P. M.
April 4, "A Tour of the Fourth National Instrument Exhibit," Slide Film No. 2.

CENTRAL ILLINOIS
H. F. Lange, 2101 W. Glen Avenue, Peoria 5, Ill.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.
April 5, Custer Hotel, Galesburg, Ill., "The Instrument Man's Place in Industry"—A round table discussion moderated by J. R. Shaffer, Corn Products Refining Co.

CENTRAL INDIANA
H. F. Coffey, 4029 N. Temple Ave., Indianapolis, Ind.
First Tuesday, Meeting at 7:30 P. M.

CHARLESTON
Claton A. Williams, 303 E. 9th St., Belle, W. Va.
First Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill.
Third Tuesday, Dinner at 6:45 P. M., Meeting at 8:00 P.M., W.S.E. Auditorium.
April 3, "Principles of Pneumatic Control," V. V. Tivy, Foxboro Co.

CHINA LAKE
A. G. DeBell, U. S. Naval Ordnance Test Sta., China Lake, Calif.

CINCINNATI
Edward H. Muhleisen, 320 Durrell Ave., Cincinnati 15, Ohio
First Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
R. M. Woodside, 332 Oakmoor Rd., Bay Village, Ohio
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society.

COLUMBUS
Orval Linehrink, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio
Third Thursday, Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md.
Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

DETROIT
Seymour Sterling, 13331 Linwood, Detroit, Mich.
Second Wednesday, Meeting at 8:00 P.M., Rackham Bldg.
April 12, "Present Day Atom Smashers," W. P. Simpson, G. E. Co., Research & Consulting Lab.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, 2558 Tyrrell Parkway, Port Arthur, Texas.
Third Tuesday. Meeting at 7:30 P.M., Lamar College.

HOUSTON
E. E. Kleir, c/o The Foxboro Co., 2518 S. Blvd., Houston 6, Texas
Last Monday, Meeting at 8:00 P.M., Engineers Club.
March 27, Banquet and Installation of New Officers.

KANSAS CITY
L. E. Oberhelman, Standard Oil Co., Sugar Creek, Mo.
First Tuesday, Meeting at 7:30 P.M., Univ. of Kansas City.

LOUISVILLE
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada
Last Monday, Meeting at 8:00 P.M. Mechanics' Hall.

NEW JERSEY
W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House.
April 4, Afternoon and evening Symposium on Measurement of pH and Conductivity.—2:30 P. M., a paper on pH by A. O. Beckman, National Technical Labs.—5:00 P. M., Social Hour and St. Louis Show Slide Films. —8:00 P.M., a paper on conductivity measurement by Dr. Rosenthal, Industrial Instruments Inc.

NEW ORLEANS
W. H. Haney, 2927 Music Avenue, New Orleans, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
Norman J. Cherry, P. O. Box 608, Merrick, L. I., N. Y.
Last Monday, Meeting at 7:30 P.M., Statler Hotel.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 9, N. Y.
Fourth Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Institute of Arts and Sciences, Buffalo.
March 27, "Derivative Action in Automatic Controls," V. V. Tivy, Foxboro Co.
April 24, Round Table Discussion, Instrument Maintenance.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

NORTHERN CALIFORNIA
M. A. Dimmick, 5607 Alta Punta, El Cerrito, Calif.
Third Monday, Meeting at 7:30 P.M., Angelo's, Emeryville.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill.
Third Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Gary Y.M.C.A.

OAK RIDGE
John H. Clark, 230 Canton Hall, Oakridge, Tenn.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada
Third Thursday, Dinner at 6:45 P. M. Meeting at 8:15 P. M.

PANHANDLE
R. E. Harris, 307 Barfield Bldg., Amarillo, Texas.

PHILADELPHIA
C. W. Wood, 6908 Market St., Upper Darby, Pa.
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
March 15, "Instrumentation in Atomic Energy," W. J. Ladnink, Oak Ridge Nat'l. Lab.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa.
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
March 27, "Automatic Control in the Oil Industry," H. F. Moore, Std. Oil Dev. Co. Also Slide Film No. 1.
April 24, "Spectro-Analysis Instrumentation," Dr. B. H. Billings, Baird Associates Inc.
Pittsburgh Inspection & Gaging Committee.
Second Tuesday, Meeting at 8:00 P.M., Wm. Penn Hotel.
March 14, "The Relationships between Engineering and Inspection," C. B. Johnson, Rockwell Mfg. Co.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa.
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd.
March 28, "Psychometry," L. G. Siegel, Case Inst. Tech.

RICHLAND
M. T. Slind, M-6, Rm. 107, Richland, Washington
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
Fred T. Yorke, P. O. Box 213, Point Edward, Ontario, Canada
Second Friday, Meeting at 8:00 P.M., Moose Hall.

SOUTH BEND
Sam M. Rouse, 436 Moccasin Ave., Buchanan, Mich.
First Thursday. Meeting at 8:00 P.M., Engineers Club, Hotel La Salle, South Bend.

SOUTH MICHIGAN
Larry DeHann, 1117 Cobb Ave., Kalamazoo, Mich.
Second Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas
First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo.
First Wednesday, Meeting at 8:00 P.M., Engineers' Club of St. Louis.
April 5, "History of Feed Water Regulators," D. Allhouse, Northern Equip. Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn.
No definite night, Dinner at 6:45 P. M., Meeting at 8:00 P.M.

TULSA
C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma
First Monday, Meeting at 6:45 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Giesiks & Pinkney, 552 Plymouth Bldg., 6th & Hennepin Ave., Minneapolis 2, Minn.
Fourth Tuesday, Dinner at 6:30 P.M.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md.
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan
Third Monday, Dinner at 6:30 P.M., Meeting at 8:30 P.M., Poremba Hotel, Ecorse, Mich.

WILMINGTON
Dean Valentine, 34 N. Hill Drive, West Chester, Pa.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

Sections Now Number 50

On February 10, 1950, the ISA Executive Committee granted a charter to the Panhandle Section ISA. This new Section, the 50th to be granted a local Section Charter, is located in Amarillo, in the Texas Panhandle area.

Secretary of the Section is Mr. R. E. Harris, 307 Barfield Building, Amarillo, Texas.

The Lone Star State can now boast of having the largest number of ISA Sections. The five are: Gulf Coast, Houston, North Texas, South Texas, and the Panhandle Section.

ERRATA: Instrumentation By and With Controlled Volume Pumps by Robert Sheen.

The following footnote references were omitted on page 57 of Volume 3 of the ISA Proceedings recently mailed out.

1. Electronics in Automatic Chemical Feed Systems. American Institute of Chemical Engineers, Vol. 42, Aug. 25, 1946, pages 725-739.

2. What the Power Engineer Needs to Know About Chemical Feed Systems for Water Treatment. Power Plant Engineering, May 1945.

3. Autcmatic pH Control in Water and Industrial Waste Treatment. Industrial & Engineering Chemistry, Vol. 39, Nov. 1947, pages 1433-1439.

4. Controlled Volume Chemical Pumps, Design and Operation. Chemical Engineering Progress, Vol. 44, April 1948, pages 327-332.

JOURNAL of the
Southern California Meter Association

President: R. Frank Fields
Vice-President: James E. Adams
Secretary-Treasurer: George H. Forster, 2916 Eucalyptus Ave., Long Beach 6, Calif.
Auditor: John T. H. Morris
Past-President: J. C. Groenewegen

SLIDE-RULE SETTINGS *for* Use *in* Measurement Work

By CHAS. J. SOYSTER, Formerly with Richfield Oil Company of California

TO the meter man, or to anyone using orifice meters, the Slide Rule is almost indispensable. Regardless how accurately we may determine an orifice meter coefficient, the fact still remains that the final gas or liquid volume computed from the meter chart is no more accurate than the least accurate step in arriving at this final volume.

Orifice meter charts measure from 3-5/8 to 4 inches from zero to the maximum reading. More than three significant figures cannot possibly be read from the chart. The scale of the smallest 5-inch slide-rule is a more magnified scale than that of the meter chart, and will yield three significant figures as easily as the chart. The final computed volume will also be accurate to three significant figures. However, when the first significant figure is 1, four figures may be read from the rule.

In the following paragraphs occasional reference is made to the C. N. G. A. Bulletin No. TS-353, "Tentative Standard Procedure for the Measurement of Natural Gas with Orifice Meters," and the S.C.M.A. Handbook Data Sheets.

Conversion of Square-Root Chart Readings to "Pound-Inch" Chart Reading: One of the most useful slide-rule settings for the orifice meter man, is that for the conversion of square-root chart readings to the old-style chart readings. It is quite possible that square-root charts will be used almost universally when a ready means is learned for translating readings from one style of chart to another. A few examples will make the method clear. Remember that pounds or inches is always on the top or A scale, and the square-root chart reading is on the bottom or D scale. In between, on the B scale, is set the range of the meter or spring as the case may be.

Example 1: Square-root chart reading is 7.65, meter maximum is 50. Find *h* (inches of water). Setting: Set index on C scale over 7.65 on D. Above 50 on B, find 29.3 inches on A. We have squared 7.65 and multiplied by 50/100. The square-root chart readings are the exact square-roots only of 100-inch meter readings in inches of water. The 29.3 inches would be converted to 7.65 by exactly the same setting. (S.C.M.A. Data Sheet 241).

Note: In setting figures on the A and B scales, it should always be remembered that figures with an even number of digits to the left of the decimal should be set on the right half of the rule, and with an odd number on the left half.

Example 2: Square-root chart reading of pressure pen is 8.85. Spring 250 pounds. What is pressure? (Zone 2.) Setting: Set index on C over 8.85 on D. Above 250 on B find 196 pounds absolute pressure on A. Subtracting Zone 2 atmospheric pressure of 14.53 from 196 gives 181.47, of which we are justified in using certainly not more than four figures, or 181.5 pounds gage pressure. Here we have squared 8.85 then multiplied by 250/100 to find absolute pressure with one setting. Remember that absolute pressures and not gage pressures are always used on the rule, and also that inches of mercury vacuum must be converted to absolute pressure in pounds per sq. in. (S.C.M.A. Data Sheet 218)

Example 3: Given square-root chart reading 5.45, using 24.7 spring. What is the vacuum in inches of mercury? (Zone 1 atmospheric pressure is 14.73) Setting: Set index on C over 5.45 on D. Above 24.7 on B find 7.35 pounds absolute on A. 7.35 from 14.73 gives 7.38 *pounds of vacuum*, which, divided by the conversion factor 0.491, gives 15.0 inches of mercury vacuum. (S.C.M.A. Data Sheet 217)

Example 4: Given 12.3 inches of mercury vacuum, using 24.7 spring. Find square-root chart reading. (Zone 5 atmospheric pressure is 13.92.) Multiply on the rule 12.3 by 0.491 (factor for converting inches mercury to pounds pressure). Product is 6.04 *pounds vacuum*: 6.04 subtracted from 13.92 gives 7.88 pounds absolute pressure corresponding to 12.3 inches mercury vacuum for Zone 5. Now set 24.7 on B under 7.88 on A. Under index on C find 5.64 on D. (S.C.M.A. Data Sheet 220A)

Atmospheric Pressure Settings for the Static Pen: A special case of the conversions given in the above paragraphs is to find the atmospheric settings for different pressure springs. Since no tables are published showing static pressure pen settings for all different pressure springs and elevation zones, the slide rule will prove to be especially useful in this case.

Example 5: What is atmospheric pressure setting for 50-pound spring on a square-root chart? (Zone 1 atmospheric pressure is 14.73) Set 50 on B under 14.73 on A. Under index on C find 5.43 on D. (S.C.M.A. Data Sheet 217)

Example 6: Find Zone 4 (Atmospheric pressure is 14.12) atmospheric pressure setting for 24.7 spring. Under 14.12 on A set 24.7 on B. Under index on C find 7.56 on D. (S.C.M.A. Data Sheet 220)

For convenience a few Standard Barometric Pressures for Different Altitudes are given from Table 17, C.N.G.A. Bulletin TS-353: (S.C.M.A. Data Sheets 217 to 220F)

Zone Number	*Elevation Limits (ft.)*	*Std. Barometric Pressure (psi.)*
1	−200 to +199	14.73
2	200 to 599	14.53
3	600 to 999	14.32
4	1000 to 1399	14.12
5	1400 to 1799	13.92
6	1800 to 2199	13.72

Gas Gravity Factors: Specific gravity factors, as given in Table 13, Bulletin TS-353 and S.C.M.A. Data Sheet 206,

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Non-members cordially invited.
FEATURE: SCMA Meter Course; Second Section, presented by W. L. Cowan and George Forster.
—THERON S. CODY
Publicity Chairman

Presented before the Southern California Meter Association, January 23, 1936. Corrected January 1950 by Southern California Meter Association.

can be read from a slide-rule to the third decimal place. We solve by dividing 1 by the gravity, and extracting the square-root, with one setting of the slide.

Example 7: What is the specific gravity factor for a gas with a gravity of 0.685? Under index on A, set 0.685 on B. Under Index on C find 1.208 on D.

Gas Temperature Factors: Table 14, Bulletin TS-353 and S.C.M.A. Data Sheet 207. In this case we divide

460 plus 60

460 plus *T*

and extract square-root with one setting.

Example 8: What is the temperature factor of gas at 150 F.? Under 460 plus 60 on A, set 460 plus 150 on B. Under index on C, find 0.923 on D.

Meter Factors, or M Values, for Square-root Charts: Table 16 of the Bulletin and S.C.M.A. Data Sheet 226. These M factors can be read with one setting of the slide.

Example 9: Find M for a 20-inch meter with a 24.7-pound spring. Set right index of B to 24.7 on A. Under 20 on B find 22.2 on D. M is equal to 1 percent of 22.2, or 0.222.

The M factor converts the "pound-inch" coefficient to the square-root chart coefficient.

Example 10: How does the coefficient or capacity of a 100-inch meter compare with that of a 50-inch meter? Set left index of B under 50 on A. Under 100 on A find 1.414 on C. The coefficient and capacity of the meter, using the same orifice, will be multiplied by 1.414, or will be increased 41.4 per cent.

Calculation of "Pound-Inch" Charts: Pressure extension book or special slide rules are not necessary, although there is some inconvenience in taking the extensions from the rule where gas is measured under a vacuum. It may be done as shown above in Examples 3 and 4, but is more easily done by making a table or graph for the particular elevation zone showing the relation between vacuum and absolute pressure. "Pound-Inch" charts are calculated with two settings of the slide. Set index on B under absolute pressure on A. Under differential pressure on B, find pressure extension on D, by using runner. Without moving runner, multiply by coefficient on C and D scales.

We might add another example under the heading of Meter Factors. Installations are not uncommon where a high-range and a low-range meter are used on the same orifice, say a 10-inch and 100-inch meter. If the 10-inch meter is reading 9.75, what should the reading be on the 100-inch meter? In this problem the square-root chart readings vary inversely as the square-roots of the meter sizes. By inverting the slide, readings of any range meter will be found on the D scale under the meter sizes on the inverted B scale. For example, set 10, the center index of the inverted B scale, above 9.75, the 10-inch meter reading. Under 100 on B, find the 100-inch meter reading for the same orifice. Likewise, under 50 inches appears 4.37, and under 20 inches is 6.89 readings of 50 and 20-inch meters respectively, for the same orifice and flow. This comparison may also be made by reading CI scale opposite A scale, without inverting slide.

An approximate rule for computing new coefficients or meter capacities for slight changes from standard orifice sizes: It can be used with a very small error for interpolating between any two of the published coefficients. It assumes that the flow varies as the square of d, which of course is not exactly true. To illustrate, given a gas coefficient of 115.14 for a 2 by 0.750 plate, what would be the coefficient for a 2 by 0.780 plate? Setting: Over 0.750 on D, set 115.14 on B. Above 0.780 on D, find 124.8 on B. This result is about 0.3 percent high.

These examples will suggest numerous others which may be solved quickly with the slide-rule.

Automatic Controls *for* Air Conditioning

By FRANK R. FITZGERALD, Minneapolis-Honeywell Regulator Co., Los Angeles 23, Calif.

THE BASIC purpose of every air-conditioning installation is *control*—that is, taking up where Nature leaves off, the job of controlling climate. In the type of installation with which this discussion is to be principally concerned, the problem is one of maintaining climatic conditions within the relatively narrow band required for maximum comfort and health. In the case of industrial applications the requirements may be even more exacting.

In any case it becomes immediately apparent that the matter of automatic-control system design is of direct importance and interest to anyone concerned with air conditioning, whether as designing engineer, installing contractor or ultimate user. For, while the selection of the proper fans, heating coils, refrigerating equipment, etc., is important, it is obvious that the finest array of the most elaborate equipment for air moving, heating or cooling cannot accomplish its intended function unless it is operating at the command of a well-designed and integrated automatic-control system.

Such a system may be as simple as a single room thermostat controlling a unit air conditioner, or it may comprise the many related control function involved in a large multi-zone central fan system; but whether simple or complex, the same two criteria will determine whether or not it is a good control system.

First, properly selected and properly related control components must be provided in sufficient *quantity* as well as quality, if the desired results are to be obtained from the investment. For instance, an air-conditioning installation can be quite disappointing if *adequate zoning* is not provided.

Second, the opposite extreme must be avoided wherein, owing to haphazard selection, an unnecessarily large number of poorly-related control components can result in an unwieldy, inordinately complex system, difficult to adjust and operate, expensive to buy and maintain.

The problem now, in deciding which controls of what types, ranges, functions, etc., should go into a control system for an air-conditioning system, would be greatly simplified if it were possible to provide control "packages" to fit say half a dozen representative installations. Unfortunately, however, there is practically no such thing as a representative air-conditioning installation. Even with thousands of control devices available in the catalogs, we occasionally encounter an application where a custom variation, not available as a standard item, would be of advantage. Then, too, new controls for doing a better job are continuously being made available by constant research and development. Even for such a basic question as to which type of operating medium to use—pneumatic, electric or electronic—there can be no pat answer, until the characteristics of the particular installation have been analyzed.

Within the scope of this discussion we can hope, of course, to cover only the more salient aspects of basic principles and representative applications of the various types of control. I might mention, however, that the control manufacturer makes available at all times the services of control specialists for the purpose of rendering unbiased assistance in matters of control system design.

TYPES OF CONTROL AND TERMINOLOGY

Since I understand that most if not all of you are familiar with industrial control, we will review only briefly and rapidly the types of control and control terminology as used in commerical or air-conditioning applications.

I *Types by Primary Source of Power or Operating Medium*

A. Electric: Transmits signals from

*Presented before the Southern California Meter Association.

sensing device by changes in electric current. Signals actuate two-position electric devices directly, or by means of relays either pneumatic or proportioning-electric devices. *Best Application*: Where the final control action is to be two-position in nature; where the number of proportioning-type valve or damper operators is relatively small and there is no existing source of air pressure.

B. Electronic: Transmits signals by minute changes in electric voltage. Electronic relays actuate any type electric or pneumatic device. *Best Application*: Where either averaging or compensated control is indicated, particularly where more than one stage of compensation is desirable; where maximum speed of response is required.

C. Pneumatic: Transmits signals by changes in air pressure. Signals actuate electric devices through relays, and pneumatic devices either directly or through relays. *Best Application*: Where proportioning type damper or valve operators are involved and the number is relatively large or source of air pressure exists; where explosion-proof conditions are to be met.

II. *Types by Control Action*

A. On-off Control: As the name implies, provides all-or-nothing response of the controlled device. *Example*: A heating valve controlled by room thermostat set at 74 degrees, with 3 degree differential. The valve remains closed as long as the temperature at the thermostat remains at the SET POINT or setting of the control index. On a drop in temperature the valve remains closed until the temperature has reached the CUT-IN POINT (i.e., the temperature at which the thermostat switch makes contact) at which time the valve goes completely open. The valve remains open through the resultant temperature rise, until the temperature has again reached the CUT-OUT POINT, at which time the valve again closes. The DIFFERENTIAL is the change in value of the controlled condition which occurs between the cut-in and cut-out points and is expressed in degrees for a temperature controller, in percent R.H. for a humidity controller, in pounds per square inch for a pressure controller, etc. (A heating thermostat is ordinarily calibrated so that the cut-out point corresponds to the set point.)

B. Proportioning Control: Provides response of the controlled device in small increments which are proportional to the amount of deviation or correction measured by the sensing device. THROTTLING RANGE (corresponding to "differential" in "on-off" control) is the term used to denote the total change in controlled condition which is required to cause complete travel of the controlled device. *Example*: A heating valve controlled by room thermostat adjusted for 4-degree throttling range, a set point of 72 degrees and so calibrated that the set point is at the middle of the throttling range. When the temperature at the thermostat is 72 degrees, the valve is one-half open; at 71 degrees the valve is three-quarters open; at 70 degrees, wide open. Similarly, on temperature rise above the set point, the valve is one-quarter open when the temperature is 73 and fully closed at 74 degrees.

Note that the temperature can be at the set point only under median load conditions. In this example it is the condition at which the heat input from a one-half open valve exactly equals the heat losses from a 72-degree space. At any other load, the result is a partial or compromise correction in which the valve can position only part-way toward the point which would completely restore temperature to the set point and, at the same time, the temperature will be corrected more nearly back to the set point than if the valve had not moved at all from the one-half open position.

This new point of compromise balance which occurs at other than median load is called the CONTROL POINT and the amount by which it differs from the set point is called load error, droop, drift, offset, etc. (I prefer "offset.") Thus it is seen that at median load, when control point and set point coincide, there is no offset; but that as load varies from minimum to maximum, the control point shifts from one extreme of the throttling range to the other, resulting in maximum offset at the extreme load conditions.

C. Floating Control: Provides response of the controlled device to whatever position may be necessary to restore the controlled condition approximately to the set point. The NEUTRAL ZONE or DEAD SPOT is the total change in controlled condition which must occur before correction is started. *Example*: Volume damper in fan discharge controlled by static pressure controller downstream from the damper. Set point is 2 in. water column; neutral zone is 0.2 in. On pressure drop to 1.9 in., motor starts driving damper toward open position and stops only when pressure has been restored to some point between 1.9 in. and 2.1 in. Final damper position may be anywhere between open and closed, depending only on the extent of the deviation and, therefore, of the correction required.

Application of simple floating control is limited to those few which have close feedback coupling between controlled device and sensing device. Most advantageous use of floating control is in AUTOMATIC RESET of proportioning control, wherein a floating control response is superimposed on the proportioning correction to minimize offset.

Basic Control Principle

Again with the time limitation in mind, any discussion of basic principles within the scope of this meeting must be rather broad and sketchy. However, there is one basic concept which, as pointed out by several authors in the last eighteen years, is a sort of common denominator of all types of control—whether the amazing human control system of sensing perceptors, sensory nerves, brain, motor nerves and muscles; complex electronic computing machines; or an automatic temperature control system. This common requirement of all control can perhaps be most simply stated thusly: For effective control there must be fed back to the controlling device a full *report* regarding the *result* of any corrective action it caused. Analysis of air-conditioning control problems in terms of this concept may perhaps explain many otherwise puzzling questions. For instance, anyone unfamiliar with control who had the patience to follow the previous discussion of types of control action might have wondered why all the concern with adjustable throttling range, differential, dead spot, etc. It would be quite reasonable to wonder why not simply make an on-off thermostat with an infinitesimally small differential and let it go at that; or—perhaps better yet—use floating control with only a microscopic dead spot or neutral zone. The answer, of course, is that if we had *instantaneous and exact feedback* to the controlling device, precise control could be accomplished with just such simple arrangements. Conversely, without stretching the feedback concept too broadly, it can be stated that the problem of effective control is complicated almost entirely by those inherent factors which impair good feedback.

A system with no feedback might be conceived as a proportioning type outdoor controller operating a valve which supplies heat to a conditioned space. The desired result is that the temperature in the space remain constantly at 74 degrees as the load changes from maximum (when it is 30 degrees outdoors) to minimum when there is no temperature difference between outside and inside. Assuming that the full capacity of the heating system exactly matches the heat losses caused by a temperature difference of 44 degrees, it seems reasonable enough to thus control the system since we will have the valve wide open at full load (30 degrees outside temperature) half open at median load (outside temperature 52 degrees) and completely closed at the no-load or fade-out point of 74 degrees outside temperature. Unfortunately, however, we would find that such things as varying differences between *rate-of-change* of outside temperature change and *rate-of-change* in heat loss from the structure; changes in load due to other than outside temperature changes, such as solar effect, changes in wind direction and velocity; any variation in number of occupants of the space; number of lights, etc., would all act to impair the control result quite drastically.

Considering next a theoretical sys-

tem which has perfect feedback as defined previously, we might conceive of a floating controller with essentially no neutral zone, located within the conditioned space, controlling a heating valve and charged with maintaining the same condition of 74 degrees throughout the range of load change from design temperature to fade-out. Since, by definition, the thermostat now has instantaneous and exact information as to the result of any action it causes, it can start a correction for the slightest deviation, regardless of the load factor which made it necessary, and can stop the correction the instant the temperature has been restored to the set point, without overshooting or undershooting. It is too bad that this is only an idle dream.

In practice we find serious impairment of feedback, *resulting from delays or lags* in getting the information back to the controller. These lags are of many kinds and sources but for our purposes we will lump them into two classifications: Control lag and transportation lag. Considering again the floating control system of the last example, this time with feedback impaired by time lags, we now find that as an accurate control system it is not very effective. Observing, for instance, the effect of an increase in load from the median point, we find that now the temperature has dropped somewhat before the controller begins to notice it, further delay may take place in the response of the valve (control lag), the response of the heating coil to changes in flow of the heating medium, and the time required to transport the heated air back to the conditioned space (transportation lag). During all of this time we can presume that the temperature was continuing to drop at the original rate, with the result that it has undershot by an amount directly related to the rate of temperature drop, versus the total lags in the system. We find further that throughout this delayed feedback period the thermostat has recognized the sustained deviation as simply a requirement for more and more heat. Consequently, even though the actual load change might have required only a small corrective valve movement, the valve actually has no choice but to continue driving to or toward the full-open position. The result is that considerable excess correction will be put into the pipe line by the time the thermostat again recognizes that the temperature has been restored. The resultant overshoot is similar to the undershoot and similarly its extent will be determined by the rate of temperature rise versus the total time lag.

From this picture, which suggests complete control instability, we can correctly conclude that in almost all practical applications, inherent lags prevent the use of simple floating control. For similar reasons the all-or-nothing response of on-off control may result in total deviations considerably in excess of the actual instrument differential.

For this reason, proportioning controls are used almost exclusively in commercial air-conditioning installations as the final space or zone temperature controls. Proportioning controls have the advantage that a small deviation at the sensing element causes only a definite and proportional corrective valve movement (for example) and not, as in floating control, continued drive that is sustained as long as the deviation persists. This results in stability, if the actual correction is also proportional to the deviation. Unfortunately, the amount of actual correction provided by a given increase of valve motion (i.e. for a given temperature deviation in degrees) will increase radically with decrease in load such as occurs in the same heating example, as outside air temperature increases from 30 degrees at "design condition" to 74 degrees at fade-out.

When the load is light, that is, near the "fade-out" condition, the excess of heating capacity waiting to respond to even slight movements of the valve, combined with the impairment of feedback due to lags, make it necessary to widen the throttling range, that is, reduce the amount of valve travel for a given temperature deviation at the thermostat. The stability thus gained, however, has been accomplished at the expense of close control, since between no-load and full-load conditions the actual control point will have been offset a total amount equal to the width of the throttling range. Thus it seems that this rose has a thorn also and that if we want close control, we just can't get there from here. Fortunately, however, it is possible to achieve stability combined with close control.

One method, already alluded to, is by automatic reset, which can be considered as a combination of proportional and floating control. With proportional control stability accomplished by a sufficiently wide throttling range, a change in load from the median point in the previous example will result, as we have seen, in offset from the control point. If we now follow up the proportional correction, however, with additional floating control which senses and corrects for—*not* the space temperature deviation but the control point deviation, the result is control with the potential accuracy of floating control, but compensated for impaired feedback. The rate of the additional correction due to the floating control component must of course not exceed the rate of control point deviation, that is, the *rate* of the offset caused by proportional response.

I trust that anyone familiar with automatic reset will recognize this explanation as a not too inaccurate, though perhaps over-simplified, delineation of the actual interaction of the proportional and floating components of automatic reset.

Another method of combining stability with accuracy is known as compensated control. This might be considered as transferring as much of the excess capacity as possible from the final control element to a control so located that the lag and feedback is minimized. Compensated control is accomplished by either pneumatic master-submaster type control or by electronic control. Electronic controls are of particular advantage since single or dual compensation averaging circuits, etc., are readily accomplished by simple resistance-sensing elements incorporated in bridge circuits with convenient means of adjusting the relative authority of each element. An additional advantage of the electronic control is that control lag due to sensing time is reduced to a minimum by the low-mass resistance-wire elements.

Typical Applications

A. A complete air-conditioning system provides heating, cooling, humidification and dehumidification. A typical control system would include the following functions: (1) Control of outside air dampers to gradually reduce outside air to minimum as temperature either drops below 60 degrees or rises above 75 degrees. (2) Space-heating thermostat to control modulating valve on heating coil. In colder climates or on systems in this area which use 100 percent outside air, a low-limit thermostat in the fan discharge would be included to over-ride the space thermostat as required to provide minimum discharge temperature and prevent cold drafts. (3) Space-cooling thermostat to control cooling by means of sequenced direct-expansion coils valves, chilled water valves, etc. (4) Space humidity controller to operate cooling equipment for dehumidification. Heating thermostat operates to provide reheat on resultant dry-bulb depression. (5) Space humidity controller to operate humidifier valve for humidification. (6) Fan interlock relays to shut off heating, cooling and humidification when fan is shut down.

B. A typical method for accomplishing zone control is by means of controlled hot and cold plenums with individual zone thermostats controlling mixing dampers. Compensated control of both hot and cold plenums either from outside air temperature, space demand as measured in differential static pressure, or by both, is desirable. A variation extensively used in large buildings extends the hot and cold plenums in the form of double ducts in corridor ceilings. Individual room thermostats control mixing dampers at duct take-offs adjacent to the respective rooms.

C. Panel heating control requires particular consideration of the lags involved—especially when a "heavy" panel is located in a "light" structure. Compensated control is a "must" preferably on both the water temperature and on the control of the panel itself. Electronic control lends itself admirably to this application. Zoning may be accomplished with space thermostats controlling three-way mixing valves supplying the respective panels.

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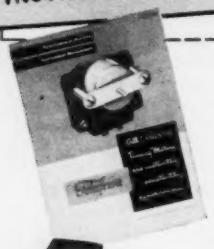

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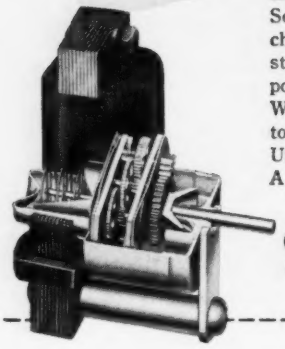

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TEMPERATURE MEASUREMENT AND CONTROL

Continued from page 247

the relation between "factory accuracy" and "sustained accuracy" is to a large extent determined by the construction of the instrument. Sustained accuracy guarantees are a challenge to the manufacturer to so construct his instrument that the most improbable abuse will not unduly affect the accuracy of the instrument.

To summarize all of this, then, if a user will carefully determine whether he is actually interested in sensitivity rather than accuracy, he can save himself much of the expense involved in continual checking and adjustment of calibration. In the long run, he will save wasted investment caused by needless effort on the part of the manufacturer to meet unduly high accuracy standards. On the other hand, modern correlation of processes puts an ever increasing demand on the manufacturer to be able to provide higher accuracy in his instruments.

Looking at the specialized problem where the sensitive element may be divorced from the instrument, as in electrical instruments, we are not, in general, concerned with sensitivity. In general, the most minute change of temperature will produce a change in resistance or voltage developed by the sensitive element. The problem of sensitivity is in developing recording or indicating instruments which will respond to these minute changes.

The major term involved in the industrial use of sensitive elements is "interchangeability." To make practical use of these elements, it is seldom satisfactory to calibrate a given instrument to a given element. Any instrument may be used with any element, and hence both must be interchangeable. The accuracy of electrical instruments is usually stated in terms of resistance, voltage, or other electrical parameter, and to obtain the accuracy of an over-all system, it is necessary to add the deviations of individual sensitive elements which may be applied to the instrument. *Interchangeability*, then, can be defined as a statement of the deviations of individual elements from a standard element.

Here again, such a statement is affected by the quality of the standards, against which the standard element is checked.

Interchangeability is directly affected by the methods used in construction, since to produce resistance bulbs, for example, of exactly the same characteristics over and over, calls for great care in the method of constructing the bulb. Furthermore, some methods of construction are inherently subject to change, owing to the effects of temperature, and this change will result in a drift of the sensitive element with age and use, which will affect its interchangeability.

Response is shown as affecting interchangeability, but, in general, just as in the determination of the accuracy of an instrument, in determination of the interchangeability of elements the effects of response are eliminated by allowing sufficient time for the sensitive element to come into equilibrium with the standard.

Here again, in many instances, considerable expense can be saved by the user by recognizing the fact that sensitivity is the paramount consideration in many jobs, and that, in general, lack of interchangeability of sensitive elements does not adversely affect the sensitivity. However, increasing correlation of processes causes an ever-increasing demand upon the manufacturer to increase the interchangeability of sensitive elements.

General Choice Between Mechanical, Filled System, Pneumatic, Electrical Instruments

In discussing the various types of temperature measuring instruments available, we have already disposed of the mechanical type operating on the expansion of a metal, and the glass stem thermometers operating on the expansion of a liquid. Let us now compare the filled system and the electrical type instruments. In general, filled system thermometers offer the greatest simplicity and usually the lowest investment. The major distinction between filled system and pneumatic transmission or electrical types is the distance between the point of measurement and the point

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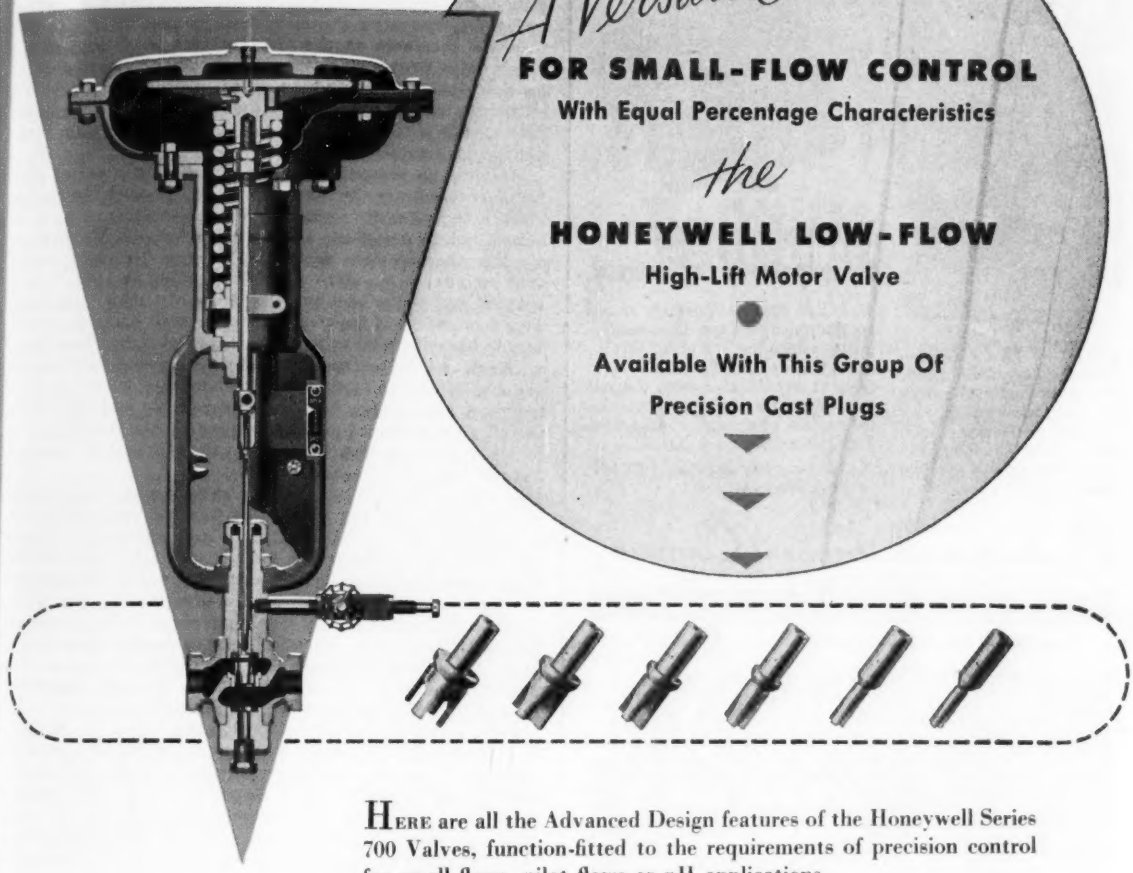

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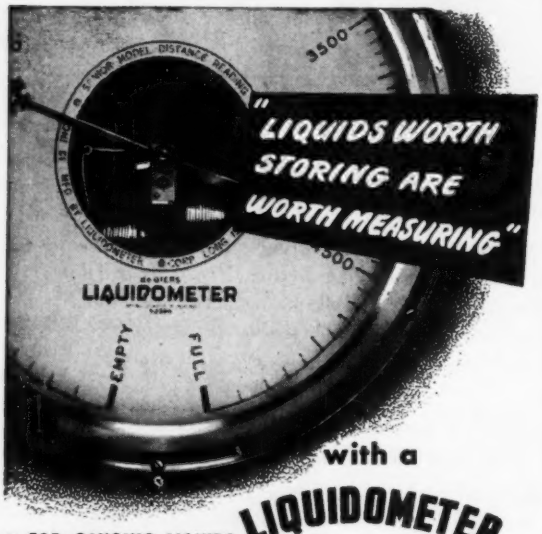

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WRITE FOR COMPLETE DETAILS

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of recording or control. In most installations, where this distance is relatively small, say under 100 feet, filled system instruments should be used. However, where the distance becomes larger, considerations of speed of response, cost of connecting tubing or cable, and ease of installation tend to dictate the use of either pneumatic or electrical instruments.

As far as the choice between pneumatic and electrical instruments is concerned, pneumatic transmission instruments offer a major advantage where explosion hazard is important, but have the disadvantage that their speed of response decreases as the distance increases. Over-all accuracy of a pneumatic system is usually less than that of an electrical system, and, in many instances, the required sensitivity cannot be obtained with pneumatic instruments, particularly if the effect of speed of response on actual sensitivity is considered.

It must be remembered, however, that the use of electronic instruments, in many instances, permits the energy level in the sensitive element and connecting cable to be so low as not to constitute an explosion hazard. Many users consider thermocouple wire and, in some instances, resistance bulb cable, the same as flexible tubing and run it bare without expensive conduit. However, in many locations, electrical code and insurance requirements make it mandatory to use expensive explosion-proof conduit for these leads.

As far as the instrument itself is concerned, most models are available with explosion-proof housings. However, these housings are usually bulky and expensive and difficult to install on instrument panels. In general, the tendency is to locate the instrument in a safe area, so that it does not have to be explosion-proof.

In this connection, it is worth-while noting that as little as ten years ago, the thought of locating an electrical instrument with the high voltages and supposedly fragile vacuum tubes contained in today's electronic instruments, in any part of a plant having hazardous areas, was unheard of. Contrast that attitude with the present situation, where electronic instruments by the hundreds and thousands are located in refineries, chemical plants, powder plants and other hazardous processes. The answer is, of course, that engineers have been able to recognize different degrees of hazard in different types of instruments and to so design control rooms as to reduce the hazard below a safe limit. It is reasonable to expect that in the future, the same attention will be paid to connecting cables and sensitive elements, and recognition will be made of the fact that, in many instances, they do not constitute a hazard, even in explosion areas. Special cables are being developed which further reduce the hazard without the expense of using explosion-proof conduit.

Some of the finer details involved in choosing between the particular types of systems to be used are the likelihood of damage to connecting cable or wiring. Damage to connecting tubing in a filled system thermometer usually necessitates the return of the instrument to the manufacturer for repair. On the other hand, damage to electrical wiring can be remedied by the plant electrician. In many installations, even where short distances are involved, this factor alone is enough to dictate the use of electrical instruments. Pneumatic transmission instruments also help in such a situation, except that there still remains a short length of tubing between the bulb and the transmitter.

One advantage that pneumatic transmission has over all other systems, of course, is that if a leak occurs, it hisses at you and is thus much easier to detect.

Where over-all dependability and continuity of operation is of paramount importance, the filled system instrument, through its inherent simplicity presents the least possibility of failure, if adequate care is taken to protect the connecting tubing mechanically. Electronic instruments run a fairly close second, however, in spite of their apparent complexity. Many years of plant use have demonstrated to users that vacuum tubes are *not* inherently fragile devices. A sidelight on this is the statement of an industrial vacuum tube manufacturer concerning the recommendations of most instrument companies that vacuum tubes be replaced once a year, to the effect that once a tube has lasted a year,

it has a better probability of lasting another year than a new tube which might replace it. It has been effectively demonstrated that vacuum tubes will either fail within the first few hours of service or will last indefinitely in the properly designed instruments now available.

Pneumatic transmission instruments are perhaps the least satisfactory from this standpoint. The transmitter itself, located as it usually is, in the field is most likely (though this likelihood still remains small) to be damaged or to become inoperative. Added to the transmitter is the receiver with its probability of failure.

Introduction of the non-indicating type of pneumatic transmitter, with its much simpler construction, has helped this situation but by no means eliminated it.

Pneumatic transmission is unique in one respect, in that it provides a simple indication of temperature at or near the point of measurement, as well as the major function of controlling or recording at the central point. Neither electrical nor filled system instruments offer this advantage.

Where accuracy is important, the electrical type of instrument usually offers the greatest over-all sustained accuracy with the filled system instrument coming next. The pneumatic type of instrument comes in last, since in general, the transmitter as an indicator will have the same accuracy as the filled system instrument and to this must be added the inaccuracy of transmission and of the receiving instrument.

Owing to the much higher force/friction ratio available in electrical instruments, particularly electronic, and because, in general, the sensitivity is not interfered with by slow response, the electronic instruments offer the higher sensitivity and hence, in many applications, the greatest degree of control. Filled system instruments with short tubing lengths, however, are nearly as good in this respect in many instances. Pneumatic transmission instruments are considerably better than filled system instruments with long tubing lengths, but still fall far short of ideal. It must be pointed out, however, that in many installations the increased sensitivity, particularly that portion of it due to the increased speed of response of electrical instruments is nullified by the use of long air lines back to the control valve. The obvious answer to this problem is electric control, and the day is certainly not far distant when an electric control system including a valve of the same simplicity as the pneumatic control system for proportioning type control must be forthcoming.

Of somewhat minor importance is the advantage of electrical measurement over filled system instruments where a number of points are to be indicated or recorded on the same instrument. Switching is, of course, a natural with electrical instrument and many types of indicators and recorders have been devised to take advantage of this fact.

It is worth noting that switching with pneumatic instruments is entirely possible with due consideration of value design to eliminate errors from leakage and interconnection.

A note of warning should be sounded, however. The fact that measurements can be switched to provide a number of measurements in one instrument does not inherently mean that a number of controllers can advantageously be mounted in one instrument. Modern processes demand continuous control and, so far at least, the only satisfactory way of doing this is to avoid switching in the control circuit. Exceptions can be made of the simpler on-off control problems, of course, but the more complicated proportioning controls essentially require one instrument per controlled temperature. Of course, two, and in some instances, three or even four proportioning controllers can be mounted in the same case where panel space is at a premium, but, in general, at some sacrifice in the recording function.

Fig. 2 summarizes this aspect of measurement.

Filled System Thermometers

The characteristics of the various types of Filled System Thermometers are too well known to require further detailed explanation here. However, a brief resume will be given to complete the picture.

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expansion of a liquid, which may be mercury or a purified hydro-carbon. The bulb, connecting tubing and Bourdon spring are completely filled with the liquid and enough initial pressure built up in the system to prevent a vapor space from forming, regardless of ambient conditions. Since an increase of temperature anywhere in the system will cause expansion of the liquid, it is necessary to provide some form of compensation for that portion of the system not immersed in the temperature to be measured. This compensation may take the form of a bimetallic spiral spring mounted in the case, which opposes the movement of the Bourdon spring caused by a change in ambient temperature. With this type of compensation, only a short tubing length, usually under 25 feet, is feasible. The volume of liquid in the tubing is thus quite small and has a negligible effect on the reading of the instrument, if the tubing and case are substantially the same temperature. The instrument thus indicates only the temperature of the bulb.

Where longer tubing lengths are needed, a dual system is used, one system consisting of the bulb, tubing and spring, and the other system consisting of only the tubing and the spring. The motions of the two systems are opposed to each other, and all changes of temperature and resultant changes of volume along the tubing or in the spring are nullified so that the pen moves only due to a change of temperature and volume at the bulb.

Fig. 2. GENERAL CONSIDERATIONS FOR CHOICE BETWEEN FILLED SYSTEM, PNEUMATIC OR ELECTRICAL (ELECTRONIC) THERMOMETER

PROBLEM	← MORE - SUITED - LESS →		
Long distance between bulb & instrument	ELECTRICAL	PNEUMATIC	FILLED SYSTEM
Sensitivity needed for controllability	ELECTRICAL	FILLED SYSTEM	PNEUMATIC
Over-all dependability	FILLED SYSTEM	ELECTRICAL	PNEUMATIC
Damage likely to connecting tubing	ELECTRICAL	PNEUMATIC	FILLED SYSTEM
Accuracy of readings needed	ELECTRICAL	FILLED SYSTEM	PNEUMATIC
Explosion hazard exists	PNEUMATIC	FILLED SYSTEM	ELECTRICAL
Switching of measurements desired	ELECTRICAL	PNEUMATIC	

Liquid filled instruments have uniform temperature scales and hence are equally readable throughout the scale. Sensitive bulbs are relatively small. The case compensated type is limited to approximately 25 feet of tubing, and the completely compensated type may be used up to 100 or more feet. However, the expense of this system is considerably higher than any other filled system. The power developed by the expansion of liquid is relatively large, so that narrow spans may be used for greater readability. Minimum spans are about 40 degrees F. Hydrocarbon filled instruments are limited in maximum temperature to approximately 500 F., while mercury filled instruments may be used up to 1000 F. On the other hand, hydrocarbon filled instruments may be used for temperatures as low as minus 300 F., while mercury filled instruments are limited to minimum temperatures of about minus 35 F.

Gas filled instruments depend upon the change in pressure of a gas, usually nitrogen, under change of temperature. To minimize errors due to changes of ambient temperature of the case and tubing, it is usually customary to use some type of bimetallic compensating spring. It is usually necessary to use rather large bulbs to insure that the volume of gas in the tubing is negligible with respect to that in the bulb. A double capillary compensating system similar to that described under liquid filled systems is also used.

Gas filled instruments cannot be used over as narrow spans due to their lower power. The minimum span is approximately 120 degrees F. Gas filled systems may, however, be used over an extremely wide temperature range, from minus 450 F. to 1200 F. Their major limitation is due to the large size of the bulb. Tubing lengths may be as great as 200 feet.

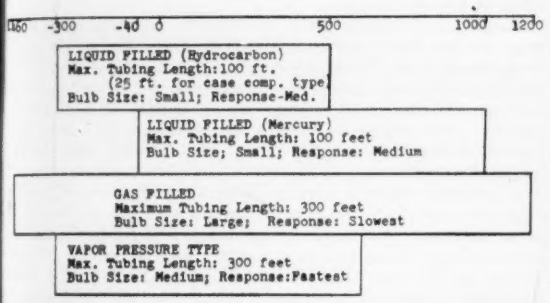
The most generally used filled system instrument is the vapor pressure type. This instrument depends upon the principle that when a liquid and its vapor are enclosed, the pressure of the vapor will be a function of temperature.

This function is quite non-linear, so that vapor pressure instruments are characterized by a scale with small divisions at the bottom of the scale and larger divisions at the top. This is an excellent feature where normal operating temperatures are higher than room temperature, but where temperatures down to room temperatures are of interest during abnormal operating conditions. A wide open scale of easy readability is then available at the operating point, but the pen will also cover the lower values on a standard sized chart.

The pressure in the system depends upon the temperature at the interface between the liquid and the vapor. The volume of the bulb is so selected that all the liquid in the system may be contained in the bulb, if the bulb is at a lower temperature than the case and tubing. Under these conditions, the interface will be located in the bulb, and the temperature of the case and tubing will have no effect upon the reading of the instrument. Conversely, if the temperature at the bulb is higher than that at the case and tubing, all of the tubing and spring will be filled with liquid but there will still be sufficient liquid to fill part of the bulb, keeping the interface in the bulb. Vapor pressure instruments need no compensation for ambient temperature.

Two special considerations must be given in the use of vapor pressure instruments. Where the bulb is at a different level from the instrument, a liquid head will exist in the tubing when the bulb temperature is higher than ambient

Fig. 3. GENERAL CHARACTERISTICS OF FILLED SYSTEM TYPE THERMOMETERS



temperature. This liquid head must be compensated for by an initial adjustment on the instrument. If the bulb temperature then goes lower than ambient temperature, and the tubing is filled with vapor, the liquid head no longer exists, and the correction would become an error. Thus, a vapor pressure instrument installation in which the bulb crosses the ambient temperature cannot be used where the bulb is not at the same level as the instrument without error. On any installation of a vapor pressure instrument where the bulb crosses ambient temperature, there will be a time lag occasioned by the liquid having to move from tubing to bulb and vice versa. In some control applications this time lag would be disastrous.

Vapor Pressure instruments may be used from temperatures of minus 300 F. to approximately 560 F. Their spans, particularly the working portion of the span, can be quite narrow, owing to the expanding scale characteristics of these instruments. They are the fastest in response, if the bulb does not have to cross ambient temperature, and hence are the most all-around useful instruments of the filled system instruments. In some instances, their non-linear scale is a handicap, and the fact that they will not stand very much overrange limits their usefulness on some applications.

Tubing lengths may be as great as 300 feet or more.

Fig. 3 summarizes the applications of the filled system instruments.

Electrical Instruments

Electrical instruments, for practical purposes, may be divided into those operated with resistance bulbs, those operated with thermocouples, and radiation type. Since the optical type does not apply to most process work no further discussion of it will be made here. Before going into the

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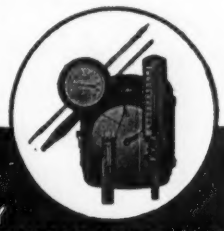

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details of electrical instrument construction, let us examine the relative merits of the three types.

The resistance type instrument measures the resistance of a coil of wire which is subjected to the temperature to be measured. Thermocouple instruments measure the voltage generated by a pair of thermocouple junctions, one at the temperature to be measured and the other at instrument temperature. Since, in general, there is no interest in the instrument temperature, some means of compensating for instrument temperature change must be made. Radiation type instruments measure the heating effect of radiant energy upon either a thermocouple or a resistance element located at a distance from the radiant body whose temperature is being measured. When a thermocouple is used in the radiation head, the same problem of cold junction compensation must be met. In this case, the actual temperature difference being measured is the difference between the exposed thermocouple junction, or junctions, and the junction or junctions which are shielded from the radiant energy. Ambient temperatures at the instrument usually do not affect the readings.

Resistance bulbs may be built to operate at temperatures from almost absolute zero up to as high as 2000 F. Thermocouples of various types may be built to operate at temperatures from approximately minus 325 F. to 3000 F. Radiation elements may be used to much higher temperatures, ranging in commercial installations as high as 3300 F. or more. Recent developments in the field have made radiation elements available for temperatures as low as 200 F. Thus, there is a decided overlap in the ranges which may be measured by the three types.

Radiation elements have a distinct advantage in that they do not have to actually contact the body or the fluid being measured. Their use in lower temperature measuring devices is usually confined to measuring the temperature of moving objects or of objects which would be marred by contact with either a bulb or a thermocouple. However, radiation elements are inferential just because they do not touch the medium being measured, and hence their accuracy and stability depends a great deal upon the way in which they are installed. In general, particularly for the lower temperature applications, it is necessary to calibrate the instruments in place and such factors as dust in the atmosphere, or the presence of other radiating bodies, may have very bad effects. Temperature scales on radiation instruments are normally quite non-linear, which makes them difficult to use over extremely wide operating ranges. The fact that their calibration and accuracy depend to a very large extent upon their method of installation and maintenance tends to make radiation units a last resort as a method of temperature measurement where other elements are unavailable.

Thermocouples have a distinct advantage in being small and relatively inexpensive. In many cases, the user can manufacture his own thermocouples with a satisfactory degree of accuracy. On the other hand, in actual use, it is usually necessary to protect the thermocouple by means of a socket or protection tube, so that the over-all size becomes comparable with the over-all size of modern resistance bulbs and resistance bulb assemblies.

Bare small-gage wire thermocouples have perhaps the fastest speed of response possible, but here again, in practical use, the wire gage must be sufficient to make the thermocouple rugged and this factor and the usually necessary use of protection tubes slows the response until it is comparable with modern resistance bulbs and assemblies.

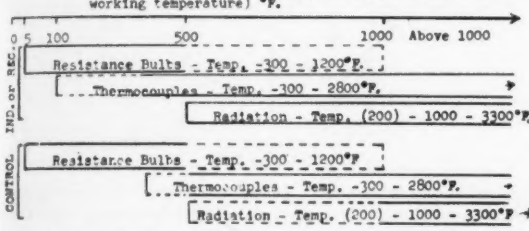
The major drawback to the use of thermocouples is the necessity of cold junction compensation. In any instrument circuit, there are additional junctions between the various resistors, capacitors or other elements of the circuit, each of which acts as a thermal junction. In practice, all these junctions are located as close together physically as practical and surrounded by a shield, so that they all tend to remain at the same temperature. A temperature sensitive element is inserted in the circuit and is also mounted within the same shield, so that an over-all change of temperature of the shielded area is sensed by the temperature sensitive element, and the necessary correction applied automatically. Even though the correcting voltages involved are extremely

small, compensation can be made quite accurate, if enough time is allowed for the temperatures in the shielded area to stabilize. In actual practice, however, the temperature in the shielded area is constantly changing and hence transient conditions are set up which prevent the compensation from ever becoming completely effective. These transient conditions are intensified in an electronic instrument by the presence of heating elements, such as the vacuum tubes and transformers, which are good sources of radiant heat to affect the shielded area. Thus, the over-all accuracy of compensation is normally not better than 1 or 2 degrees F. under normal ambient temperature changes.

Small variations of this order are not important where the instrument scale covers a fairly large span. In general, it may be stated that if the instrument scale is more than 500 F. wide, other errors will be larger than the compensation error. However, if it is necessary to go to a narrower span instrument, the compensation error becomes important. In control applications, compensation errors lead to control point instability, so that even though the pen may be drawing a straight line, the actual temperature (and end product quality) may be wandering, owing to compensation errors.

Here again, the width of the scale is a criterion as to the importance of the compensation error. If the process can be controlled with an instrument with a span of greater than 500 degrees F., it normally will not be upset by compensation errors. However, if such an instrument does not give adequate control, it is rather useless to go to a narrower span instrument in an effort to improve control.

Fig. 4. CRITERIA FOR CHOICE BETWEEN RESISTANCE-THERMOCOUPLE-RADIATION WIDTH OF SCALE (Span covered regardless of working temperature) °F.


0 5 100 500 1000 Above 1000
IND. or REC.
Resistance Bulbs - Temp. -300 - 1200°F.
Thermocouples - Temp. -300 - 2800°F.
Radiation - Temp. (200) - 1000 - 3300°F.
CONTROL
Resistance Bulbs - Temp. -300 - 1200°F.
Thermocouples - Temp. -300 - 2800°F.
Radiation - Temp. (200) - 1000 - 3300°F

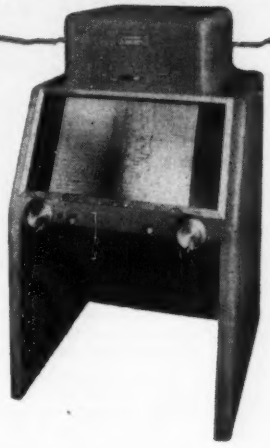
Resistance bulbs have a distinct advantage in not requiring compensation. The limiting factor in over-all stability in a resistance instrument is the stability of the resistance bulb itself and of the instrument. Since the over-all stability of the instrument is usually a constant whether the full scale of the instrument covers 500 or only 50 degrees F., and since the instability of resistance bulbs can be made a negligible factor, resistance instruments are usually capable of closer control than any other form of measurement where narrow spans are feasible.

It might be noted in passing that before the advent of the electronic instrument, the sensitivity of the galvanometer was the limiting factor as to the narrowness of the instrument span. This is no longer true with electronic instruments in general, but for spans of less than 500 degress F., the resistance type of measurement normally offers a greater stability.

Obviously, for temperatures above that at which resistance bulbs may be used, it will be necessary to use thermocouples, but fortunately, temperatures in this higher range are not usually critical to a matter of a degree or two. The obvious advantages of the resistance type of measurement have forced the design of resistance bulbs for ever increasing temperatures. A few years ago, standard bulbs were not available for temperatures above 600 or at most 1000 F. At this time, however, a number of manufacturers make resistance bulbs for use as high as 2000 F. and constant exploration of new materials will undoubtedly produce resistance bulbs for even higher temperatures.

Constant improvements in resistance bulb manufacture have now made available resistance bulbs which may be used in sockets without sacrifice of speed of response, and without requiring special sockets. The cost of replacement elements is being driven down. At the present time, replacement elements are available for one-quarter the cost generally in force ten years ago. Another factor in cost is that

New TELEREADER



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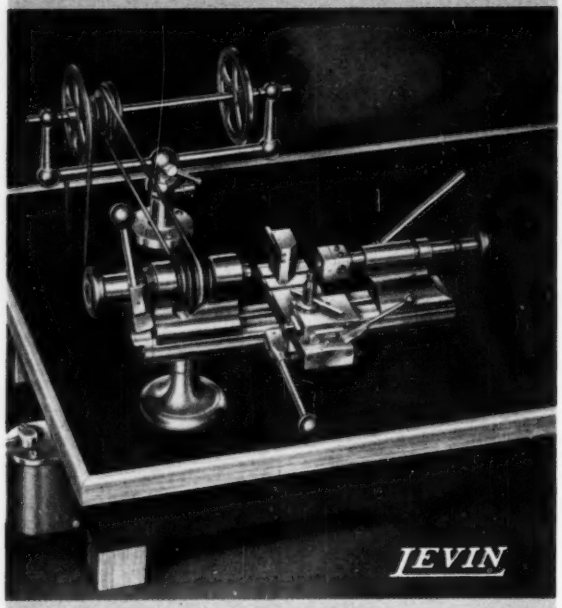

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resistance bulbs are generally more rugged in construction than thermocouples and hence do not require replacement as frequently.

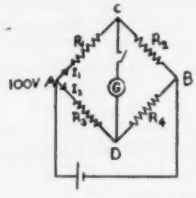
Fig. 4 gives a summarization of the relative applications of electrical types of measurement.

Circuits of Electrical Instruments

Perhaps the best way of discussing the various forms of electrical instruments available is to touch briefly upon the basic circuit principles utilized.

The simplest form of electrical instrument is the direct deflection type, which is essentially an indicating voltmeter. For thermocouple and thermocouple radiation elements, a high resistance d'Arsonval type movement is used. The higher the thermocouple voltage, the larger the current drawn through a direct deflection instrument and the greater the deflection. A high resistance circuit keeps this current and the consequent I-R drop in the thermocouple and lead lines to a minimum. However a baisc limitation of this type of instrument is that this I-R drop is still present, and unless the thermocouple and lead line resistance is held constant, it results in relatively large errors.

Another drawback of this type of instrument is that there is little power available for such functions as controlling and recording. Recording instruments have been made which periodically depress the pointer against an inked



$I = \frac{E}{R}$ $E = R \times I$

$E_1 = R_1 \times I_1$

$E_2 = R_2 \times I_2$

$\frac{E_1}{E_2} = \frac{R_1}{R_2}$

Fig. 5

tape, which in turn makes an impression at the appropriate point on a chart. The mechanical maintenance and inaccuracy of such instruments have virtually obsoleted them at this time in favor of the more rugged potentiometric type instruments.

Control of an essentially on-off nature may be effected with these instruments through the use of capacitance or inductance elements through which the pointer passes triggering off an electronic circuit to operate relays. Sharpness of control is entirely adequate for many simple control jobs, but is limited by the instability of the control pick-up and the errors of the deflection system. Controllers of this type are, however, the least expensive electric controllers available, and their use is widespread for simpler control jobs.

One example of a recording instrument operating on the deflection principle that is now generally available utilizes the same type of electronic pick-up mechanism to drive a reversing motor which positions the pen on a strip chart in accordance with the position of the pointer. The sensitivity of this instrument is relatively low, though adequate for some recording jobs. It, of course, suffers from the same limits of accuracy as the deflecting pointer itself.

Most of the remaining types of electrical instruments operate on some variation of the Wheatstone bridge. A Wheatstone bridge consists basically of four resistances connected in a network, as shown in Fig. 5, with a source of voltage applied across points A and B. From the fundamental Ohm's Law that the current flowing through a resistor is equal to the voltage across the resistor divided by the resistance of the resistor, we may deduce that the voltage drop across a given resistor is equal to the product of the resistance times the current flowing.

For simplicity, let us assume that the battery supplying voltage across points A and B has a value of 100 volts, and that point B is grounded or at zero potential. The current flowing through resistances R1 and R2 will then equal 100 volts divided by the sum of R1 and R2. However, the same current will flow through both resistors, since there is nowhere else for it to go. Similarly, the same current, I2, will flow through resistors R3 and R4, though this current will be different from I1 unless the sum of R3 and R4 is equal to the sum of R1 and R2.

The voltage drop through R1 will then be E1 equaling R1 times I1. The voltage drop through R2 will be E2 equaling R2 times I1. The ratio of voltage drop, E1 to E2, will be the same as the ratio of the resistances R1 to R2, since the current cancels out.

Let us now assume that R1 is 100 ohms and R2 is 300 ohms. The

voltage drop then through R2 will be 3 times that through R1. In other words, one-fourth of the voltage drop will occur in R1 and three-fourths of the drop will occur in R2. One-fourth of 100 volts is 25 volts, so that a 25-volt drop will occur in R1 putting point C at 75 volts. Following through, three-fourths of 100 volts is 75 volts, making the voltage drop through R2 75 volts and making the voltage at B zero, as we started out.

It should be noted that the relative voltages in the A-C-D section of the bridge will be unaffected by changes in resistance in the A-D-B section of the bridge, unless, of course, the resistances on either side became so low as to draw down the battery voltage. Hence, as long as R1 equals 100 ohms and R2 equals 300 ohms, the voltage at C will be 75 volts, regardless of the values of R3 and R4.

Let us assume that R3 is 200 ohms and R4, 600 ohms. By the same reasoning as we went through above, three-fourths of the voltage drop will then occur in R4 and only one-fourth in R3, and point D will also be at 75 volts. If we now close the switch to voltmeter, and connect it between points C and D, we will see zero voltage indicated, since both points C and D are at the same voltage. Under these conditions, the bridge is said to be in balance.

Let us now assume that R4 is a resistance bulb, and that its resistance has changed as a result of a change of temperature to a value of 200 ohms instead of the original 600 ohms. Since R3 now equals R4, the voltage drop through them must be equal or one-half of the voltage drop occurs in each resistor. Thus, point D is now at 50 volts. If we consider our voltmeter to be an extremely high resistance voltmeter so that negligible current is drawn between points C and D, we will see that the voltmeter will now register 25 volts. Let us define this 25 volts as negative, since point D is lower in voltage than point C.

We can rebalance the bridge by making R2 a rheostat and adjusting it to a value of 100 ohms, which is equal to R1. This makes the voltage drop through R1 and R2 equal, so that point C will now be at 50 volts and our voltmeter will again read zero volts.

If our resistance bulb, R4, is now subjected to an increased temperature again and returns to its original value of 300 ohms, point D will become 75 volts and our voltmeter will show a deflection of 25 volts in the opposite direction, since point D now is higher than point C in voltage.

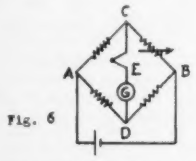


Fig. 6

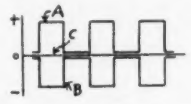


Fig. 7

Here we have all the essentials for automatic balancing. We have a voltmeter, or a galvonometer which shows zero deflection when the bridge is balanced, deflects one way when the temperature decreases and deflects the other way when the temperature increases. From the above discussion, you will note that R2 is always in the same ratio to R4, when the bridge is balanced, as R1 is to R3. Since we know the ratio of R1 to R3, we can calibrate R2 in terms of the resistance of R4 and, in turn, in terms of the temperature of resistance bulb R4.

Mechanical resistance type instruments generally operate on this scheme. The position of the galvanometer pointer is detected mechanically by various means, and the amount of its deflection causes a motor to drive a rheostat or slidewire in the proper direction and amount to rebalance the bridge. The actual calibration of the voltmeter is unimportant, since it will only affect the speed with which the slidewire contact and attached pen will balance. As long as the galvanometer returns to a given position for zero voltage, the pen will read correctly.

When it is desired to use this type of instrument for measuring thermocouple voltage, the thermocouple may be inserted in series with the galvanometer as shown in Fig. 6. In this instance, the bridge is purposely unbalanced to create a voltage between D and E exactly equal and opposite to the voltage created by the thermocouple between points C and E. These two voltages cancel and the galvanometer shows zero voltage difference between points C and D. In this case, a slidewire is calibrated in terms of the voltage unbalance it creates in the bridge and, in turn, in terms of temperature of the thermocouple producing the bucking voltage.

An interesting use of this principle is made in the Foxboro "4000 Type" Potentiometer Controllers. In these instruments, the slidewire is positioned manually so that the galvanometer will indicate zero unbalance when the thermocouple reaches the desired temperature. A motor-driven chopper bar detects the position of the galvanometer pointer every ten or twenty seconds. If the temperature decreases, the galvanometer deflects slightly to the left, the chopper bar falls past it and actuates one set of contacts. If the

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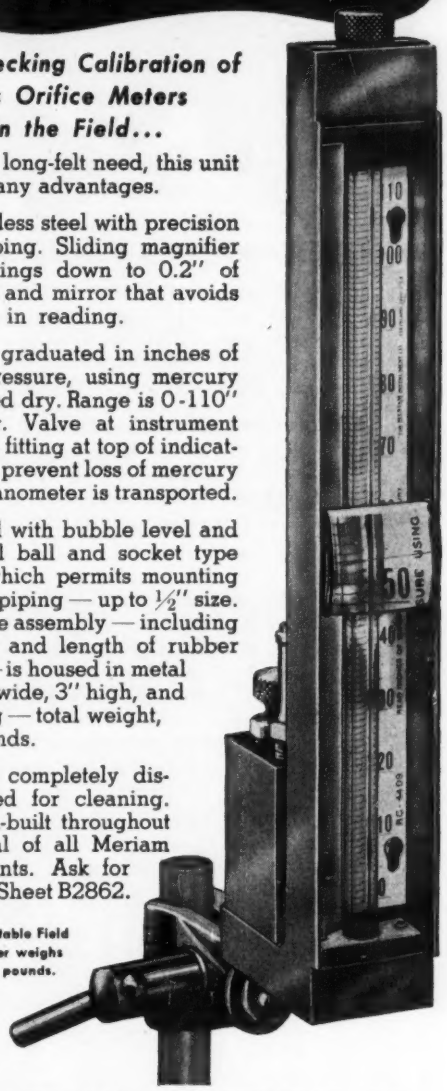

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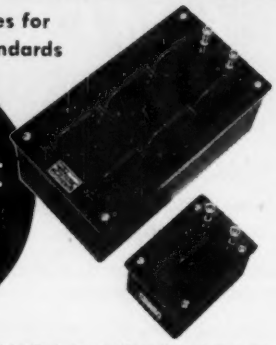

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temperature increases slightly and the galvanometer deviates slightly to the right, the chopper bar falls on top of the galvanometer pointer and actuates a different set of contacts. The instrument is a true null balance instrument and, in common with other instruments of this type, draws negligible current from the thermocouple at the balance point. Hence, the lead wire resistance does not affect accuracy, but only affects the sensitivity.

If we use the basic circuit shown in Fig. 6 and replace the galvanometer with a chopper or vibrator, the unbalance voltage will appear as an alternating voltage. If the unbalance is in one direction, the unbalance voltage will appear as in line A in Fig. 7. If the unbalance voltage is in the other direction, it will appear as in line B. If there is no unbalance voltage, the chopper will have no effect and there will be no voltage as in line C. A simple alternating-voltage vacuum-tube amplifier may be used to greatly amplify the unbalance voltage shown in Fig. 7. By passing this voltage through a phase discriminator, which will be

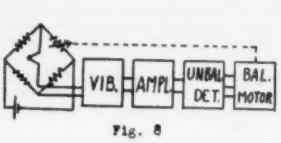

Fig. 8

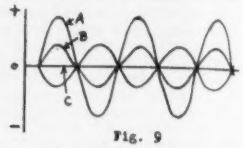

Fig. 9

discussed briefly below, it may be used to drive a reversible motor to position the slidewire contact. This eleminates the galvanometer and, by making it possible to detect much smaller unbalance voltages, greatly increases the sensitivity of the instrument. The final block diagram is something similar to Fig. 8.

In all of these instruments, it is necessary to standardize the supply voltage, since, if we refer back to our original discussion, it will be noticed that the actual voltage existing at points C and D, and hence their voltage difference, depend upon the voltage supplied by the battery. This standardization is normally done by comparing the voltage of the battery to that developed by a standard cell, which has a very constant voltage, and adjusting a rheostat in the battery line until the voltage supply to the bridge is a known value. This standardization may be done manually or automatically at definite intervals. There are some disadvantages to standardization in that it interrupts the recording or controlling process, and if neglected, or if battery changing is neglected, large errors may result.

If we go back to Fig. 5 and make the Wheatstone bridge an alternating instead of direct voltage bridge by replacing the battery with an alternating voltage source, we will find that when the bridge is balanced, the voltage at C will always be exactly equal to the voltage at D, even though the source voltage is varying, as in line A of Fig. 9. By a simple derivation, but one which would take too long at this time, it can be shown that if the bridge is unbalanced in one direction, the unbalance voltage will be an alternating voltage of the same frequency as the source and varying as shown in line D of Fig. 9. If the bridge is unbalanced in the other

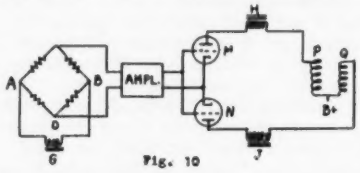

Fig. 10

direction, the unbalance voltage will vary as in line C. Obviously, if an alternating-current voltmeter were placed between points C and D, it would show whether the bridge was balanced or unbalanced, but would be incapable of showing which direction, so that it could not be used for automatic balancing. Here again, however, the unbalance voltage may be passed through an amplifier (without need of a vibrator, since it is already alternating) and greatly amplified and then passed through a phase discriminating circuit which detects which direction the bridge is unbalanced and drives a reversible balancing mechanism to reposition the slidewire.

A simple phase discriminator circuit which is used quite generally is shown in Fig. 10, the block diagram of this type of instrument. The unbalance voltage, as shown in Fig. 9, is impressed between the grid and the cathode of two triode vacuum tubes. Transformer windings G, H and

J are secondaries of the same transformer. Thus, winding G supplies the source voltage shown in line A, Fig 9. Winding H is so connected that the plate of tube M is positive at the same time the source voltage is positive, while winding J is connected so that the plate of Tube N is negative when the source voltage is positive. When the bridge is balanced, and there is no unbalance voltage, tubes M and N act as simple rectifiers, and the current flowing in coil P, is shown by line A in Fig. 11. The current flowing through coil Q is shown by line B in Fig. 11. Owing to the connection of winding J, these two currents are equal and opposite so that equal pull is exerted by coils P and Q. The voltages

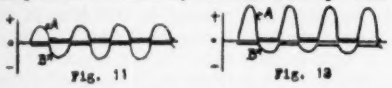

Fig. 11

Fig. 12

are 90 degrees out of phase, but the filtering effect of the coils and the inertia of the cores in the two coils, or of an armature, if the two coils are the fields of a reversible motor, prevents oscillation.

If the bridge were unbalanced in one direction so that the output voltage appeared as in line B in Fig. 9, every time the plate in tube M became positive, the grid in tube M would also become more positive and permit more current to flow through coil P. At the same time, every time the plate in tube J became positive, the grid in tube M and N would become more negative and less current would flow through coil Q. The result would be shown as in Fig. 10. This would result in unequal pull in coils P and Q, and if the armature were connected to a slidewire, would cause it to move until the unbalance voltage is reduced to zero, and the current and pull of the two coils was again equalized.

Similarly, if the bridge was unbalanced in the other direction, so that the unbalance voltage appeared as in line C of Fig. 9, the pull would be reversed, and the slidewire would be moved in the other direction.

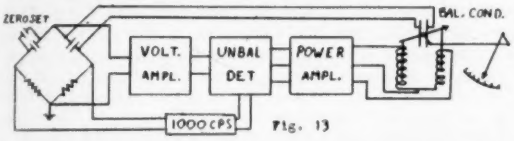

Fig. 13

It will be noted that the vacuum tubes in all of these electronic instruments do not affect the calibration of the instrument in that they merely amplify unbalance voltage.

The basic principles of this type of circuit are used in most of the resistance type electronic instruments today. One type utilizes a similar circuit, except that it uses saturable core reactors for power amplification. In all of these instruments, coils P and Q would represent the fields of a reversible motor.

Going back to Fig. 10, since we are now operating on alternating current, we can substitute a capacitor for resistor R1, and so select the capacitor that it will have an impedance at a given frequency equal to the impedance of resistance R1. By applying capacitors to both sides of the bridge that is in place of both R1 and R2, the impedance ratio will remain constant, even through frequency changes, so that the bridge balance will be independent of frequeney.

This is the principle shown in Fig. 13 and is used in the Foxboro Resistance Dynalog, where one capacitor is mounted on the rotating shaft of the crossarm and is repositioned instead of repositioning the conventional slidewire. Use of a balancing capacitor of the air type eleminates slidewire wear and removes the limit of sensitivity caused by the turn-to-turn steps of a slidewire.

Since the pen of a circular chart instrument only moves 45 degrees, the balancing capacitor is designed to have only 45 degrees full travel. This permits replacing the conventional motor and gears with a pair of opposed solenoids as shown in Fig. 13.

The major remaining type of electronic instrument, which has not been covered above, is the Foxboro EMF Dynalog instrument. This instrument operates on a unique type of measuring circuit, which may be briefly described as follows:

If a capacitor is connected to a source of voltage and

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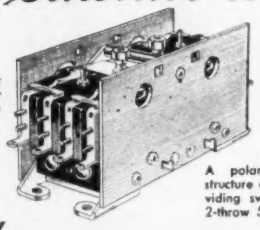
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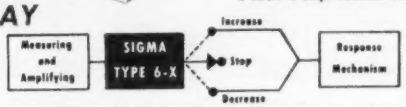

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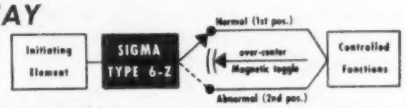

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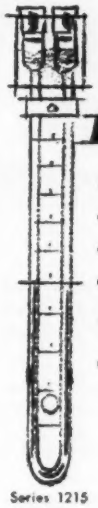
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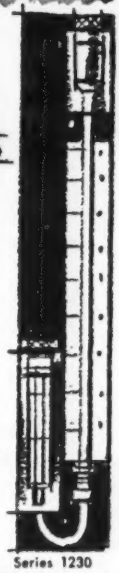
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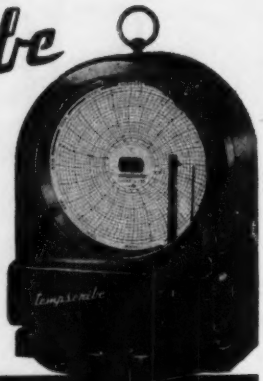

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40° to 100° F	24 Hours
60° to 90° F	24 Hours
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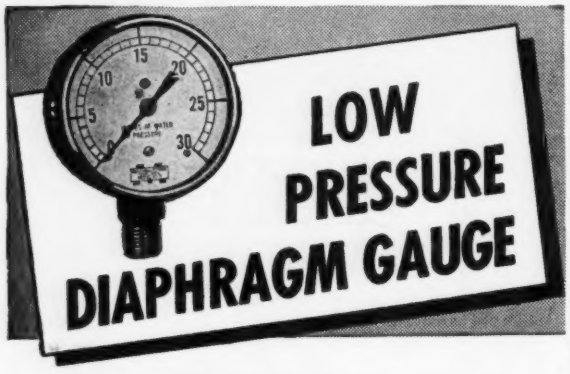

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fully charged, the charge, or amount of electricity stored in the capacitor will be equal to the capacitance times the voltage. This is, of course, as exact a law as $I = E/R$. In the Foxboro EMF Dynalog instrument one capacitor of known value is charged from the thermocouple and another variable capacitor is charged from the standard cell. These two capacitors are then discharged into each other. If the two charges happened to be exactly equal, they would dissipate into each other and there would be no resultant voltage left over. In other words, there would be no voltage between points C and D of Fig. 14. If, however, the charge in capacitor B were greater than that in capacitor A, point C would be negative with respect to D, owing to the resultant for left-over charge. On the other hand, if the charge in capacitor A were greater than that in capacitor B, point C would be positive with respect to D. This alternate charging and discharging is carried out by a vibrating switch operating at line frequency. Thus, 60 times a second, either a negative or a positive pulse of voltage will appear between points C and D, unless the two charges are equal. A plot of the voltage between points C and D would look the same as that shown in Fig. 7, which is repeated here for convenience.

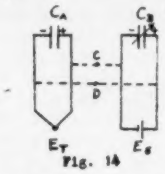

Fig. 14

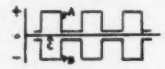

Fig. 7

The unbalanced voltage is amplified and phase discriminated in exactly the same way as in Fig. 10 or 13, windings H and J in this case being secondaries of the same transformer which supplies the voltage to the vibrator. If the pulse is negative, the two coils P and Q will reposition balancing air capacitor B so as to decrease its capacitance. This will continue until the capacitance of B has been decreased enough to make the charge in B equal to the charge in A. At this point, there will be no unbalance voltage and the instrument will come to rest. Since the two charges are equal, the two products $C_A \times E_T$ and $C_B \times E_S$ must be equal. Since C_A is known, as is E_S, the voltage of the standard cell, the balancing capacitor and the connected pen can be calibrated in terms of the unknown voltage E_T and in terms of the thermocouple temperature.

In this instrument, the advantages of the balancing capacitor are retained and, in addition, owing to the fact that only a minute current is needed to charge capacitor C_B, the current can be drawn directly from the standard cell, eliminating the need for a battery or for standardization. The same small value of current is drawn from the thermocouple. Since at the time the capacitor C_A is fully charged and the thermocouple voltage is actually being measured, there is no current drawn from the thermocouple, the impedance of the thermocouple lead lines may be many tens of thousands of ohms without affecting the operation of the instrument in any way.

Conclusion

Thus, we see that there are many types of temperature measuring instruments. In all of them, careful consideration must be given to the methods of installation of the sensitive element. No instrument can measure a temperature unless the sensitive element is actually subjected to that temperature. If the element is insufficiently immersed, it will read some average between the actual temperature and surrounding ambient temperatures. If it is located in a pocket, it will not receive prompt notification of change in temperature, and no instrument can overcome this difficulty. All forms of instruments have their place. It is foolish to attempt to overcome poor installation, or, for that matter, the poor design of a process unit merely by installing an electronic instrument in place of a filled system instrument. The vast majority of present-day applications can be admirably met by filled system instru-

ments, but, on the other hand, the greatly increased potentialities of the electronic type instruments for sensitivity, speed and accuracy should not be neglected because of their apparent complexity, or because of archaic codes of installation.

Virtually unexplored fields in industrial temperature measurement and control will be tapped through the more general use of such things as thermistors and through the development of electrical controls. All in all, it seems safe to conclude that ever increasing demands in process temperature measurement and control will continue to be met by increasing development and refinement of instrumentation principles.

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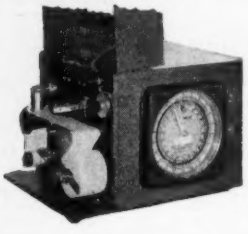

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S-123 HYDRAULIC WEIGHING SYSTEMS. 20-page Bulletin 303 describes and illustrates maker's portable hydraulic weighing system components for industrial and laboratory use (hydraulic cells, crane scales, portable cells, indicators, hydraulic jacks and hand pumps); lists features, specifications.—Testing Equipment Dep't, The Baldwin Locomotive Works, Philadelphia 42, Penna.

S-124 FLOW-RATE INDICATOR. 4-page Catalog 96 illustrates and describes maker's "Magna-sight" flow-rate indicator for coolants, lubricants, opaque liquids, slurries, etc.; covers design, operation and installation, specifications.—Fischer & Porter Co., Hatboro, Penn.

S-125 VIBRATION DAMPING INSTRUMENT MOUNT. 2-page Bulletin 160 describes and illustrates maker's "Instru-mount" vibration-damping non-magnetic base for supporting mechanical, optical or electrical instruments; lists features, capacity.—Eberbach & Son Co., Ann Arbor, Mich.

S-126 OIL COMPARATOR AND COLORIMETER. 4-page Catalog 605-50 illustrates and describes maker's oil comparator and oil colorimeter employing non-fading glass color standards; lists features, specifications of each.—Hellige, Inc., 3718 Northern Blvd., Long Island City 1, N. Y.

S-127 "hp JOURNAL." 4-page Vol. 1, No. 5 issue of this house organ features an article titled "Greater Reliability in UHF Impedance Measurements."—The Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-128 "THE GENERAL RADIO EXPERIMENTER." 12-page, Vol. XXIV, No. 8 issue of this house organ features article titled "Simple, Complete Coaxial Measuring Equipment for the UHF Range"; illustrates and describes maker's equipment for standing-wave, power, and voltage measurements.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-129 TIME CYCLE CONTROLLER. 16-page Bulletin 98154 illustrates and describes maker's "Flex-O-Timer" time cycle controller; covers operation, applications and typical installations of the several models; lists ordering instructions.—Taylor Instrument Cos., Rochester 1, N. Y.

S-130 SYNCHRONOUS AND INDUCTION MOTORS—4-page bulletin describes and illustrates maker's general-purpose synchronous and induction motors for lower fractional-hp. range; gives features, ratings, dimensions.—Holtzer-Cabot, Inc., Boston 19, Mass.

S-131 PHOTOELECTRIC SWITCH. 2-page bulletin illustrates and describes maker's twin-beam photoelectric switch; lists features and advantages, applications, operating data, accessories.—Detect-o-Ray Co., 2622 N. Halsted St., Chicago 14, Ill.

S-132 OPTICAL BENCH ASSEMBLY. 4-page Bulletin 174-50 illustrates and describes maker's "L36ON" optical bench assembly (lathe-type bench, collimator, light source, targets and filters, nodal slide) for testing lenses, mirrors, and optical systems; also describes Foucault knife-edge attachment (accessory).—The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

S-133 ENGRAVED NAMEPLATES. 4-page folder illustrates and describes maker's engraved laminated plastic nameplates; covers features, advantages, ordering instructions.—Industrial Nameplate Service, Box 5005, Houston 12, Tex.

S-134 GONIOPHOTOMETER. 2-page announcement illustrates and describes maker's "Hunter" goniophotometer for measuring manners in which flat specimens reflect, transmit light with changing directions of illumination and view; lists applications.—Henry A. Gardner Lab., Inc., 4723 Elm St., Bethesda 14, Md.

S-135 CARTESIAN MANOSTAT. 4-page Bulletin CM.97 describes and illustrates maker's Cartesian manostat "No. 6" for automatic vacuum and pressure control; covers development, construction, operation and applications.—The Emil Greiner Co., 20-26 N. Moore St., New York 13, N. Y.

S-136 TENSILE TESTER. 4-page bulletin describes and illustrates maker's "Model TT-B" electronic tensile tester for autographically recording load-elongation properties, hysteresis, relaxation effects; gives data, applications.—Instron Engineering Corp., 2 Hancock St., Quincy 71, Mass.

S-137 "THE INSTRON TENSILE TESTER." 8-page reprint of article from October 1949 issue of Transactions of the ASME describes and illustrates use of maker's electronic tensile tester (see above) in various applications.—Instron Engineering Corp., 2 Hancock St., Quincy 71, Mass.

S-138 CONTACT INSTRUMENT-RELAY. 2-page bulletin illustrates and describes maker's "Simplytrol" contact-making electrical indicating instrument for operation and process controls; covers method of operation, features, prices and ranges.—Assembly Products Inc., Chagrin Falls, Ohio.

S-139 PANEL INSTRUMENTS. 2-page bulletin describes and illustrates maker's instruments for indicating electric current; covers advantages, ranges.—Assembly Products Inc., Chagrin Falls, Ohio.

S-140 DENSITY AND GRAVITY MEASUREMENT. 12-page Catalog 76 illustrates and describes maker's "Pycnorator" instruments for measurement and control of fluid density and specific gravity; covers features and applications.—Fischer & Porter Co., Hatboro, Penna.

S-141 LABORATORY MIXER. 6-page brochure illustrates and describes maker's counter-rotating laboratory mixer; covers applications, specifications.—Brookfield Engineering Labs., Inc., Stoughton, Mass.

S-142 TITRATION RECORDER. 4-page Bulletin CEC-1810A describes and illustrates maker's "Model 26-102 Titrilog" for continuous recording of trace quantities of sulphur compounds; discusses performance, operation, specifications, rental service.—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.

S-143 "MODERN PRECISION." 8-page Vol. 9, No. 4 issue of this house organ features articles on maker's "Rayotube" radiation detector, "Steam Homo Method" for stress relief of brass parts, and use of maker's products in metals, ceramics, power, and process industries, and in research, teaching and testing.—Leeds & Northrup Co., 4902 Stenton Ave., Philadelphia 44, Penna.

S-144 "ELECTRONIC PNEUMATIC MECHANICAL INSTRUMENTATION." 32-page Vol. 4, No. 3 issue of this house organ features articles titled "High-speed Reheating of Seamless Steel Tubes," "High-pressure Laboratory Work Speeded by Automatic Controls," "Modern Continuous Brick Plant Instrumentation," pictorial on "Progress Parade of Process Instrumentation," and other articles.—Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

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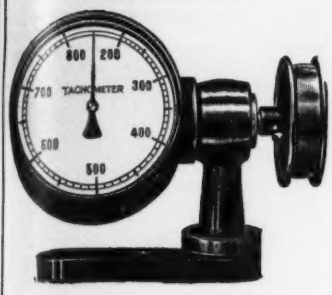

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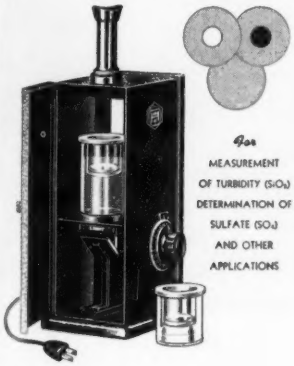

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S-148 POCKET CHAMBER ELECTROMETER. 4-page Bulletin S65-723 describes and illustrates maker's "Model 4SN3A1" pocket chamber electrometer for reading "pencil" type pocket ionization chambers; lists features, specifications, principle of operation.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

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S-153—"BURRELL ANNOUNCER." 16-page, No. 50-1-37, issue of this house organ features article titled "Phase Contrast Microscopy," and items on maker's chain balance, mercury still, torsion balance, and electric furnaces.—Burrell Corp., 1942 Fifth Ave., Pittsburgh 19, Pa.

S-154 OSCILLOSCOPE. 4-page Buletin S64-534A describes and illustrates maker's 5-inch oscilloscope for general-purpose laboratory use; lists features, specifications.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-155 "THE OHMITE NEWS." 2-page January 1950 issue of this house organ contains items on maker's Ohm's law calculator, high "Q" r-f. chokes, rheostats and resistors.—Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago 44, Ill.

S-156 SWEEP GENERATOR. 4-page Bulletin S64-811 illustrates and describes maker's "Type ST-4A" sweep generator for laboratory and TV servicing; lists features, specifications.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-157 MERCURY PLUNGER-TYPE RELAYS. 26-page catalog illustrates and describes maker's line of mercury plunger-type relays (time delay relays, quick-acting relays, load relays, etc.); gives dimensions, ordering information; discusses factors in selecting relays, special mounting arrangements.—The Adams & Westlake Co., Elkhart, Ind.

S-158 MARKER GENERATOR. 4-page Bulletin S64-810 illustrates and describes maker's "Type ST-5A" marker generator; lists features, specifications. —Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-159 SMOKE AND COMBUSTION INDICATORS. 8-page Bulletin 431 illustrates and describes maker's smoke and combustion indicators; covers construction, operation and use. —Ess Instrument Co., 95 S. Washington Ave., Bergenfield, N. J.

S-160 R-F. CAPACITOMETER. 4-page Bulletin S64-581 describes and illustrates maker's

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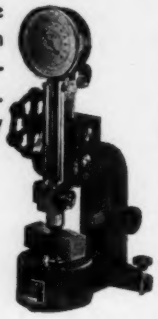

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S-164 FLAME FAILURE ALARMS. 6-page Bulletin 588 illustrates and describes maker's flame failure alarms; covers principle of operation, application, specifications, installation.—Ess Instrument Co., 95 S. Washington Ave., Bergenfield, N. J.

S-165 ELECTRICAL TESTING INSTRUMENTS. 2-page folder describes and illustrates maker's instruments for general field, shop or laboratory testing (insulation, and ground resistance measuring instruments; instrument current transformers, insulation breakdown testing instruments, a-c. voltammeter, tachometers, etc.).—Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill.

S-166 COMBUSTION INDICATORS AND RECORDERS. 2-page Bulletin 801 describes and illustrates maker's "Haxegage" combustion indicators and recorders; covers range, specifications, features.—Ess Instrument Co., Bergenfield, N. J.

S-167 UNIVERSAL ROTAMETERS. 12-page Bulletin 18-RB illustrates and describes maker's universal rotameters; covers operation, advantages, rotameter formula, method of selection, capacities and specifications for each model.—Dep't M-A, Schutte and Koerting Co., 12th and Thompson Sts., Philadelphia 22, Pa.

S-168 DISTORTION, NOISE ANALYZER. 4-page Bulletin 165-11 describes and illustrates maker's "Type YDA-1" distortion and noise analyzer for broadcast and laboratory use; covers features, specifications, principle of operation.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-169 TURBIDITY RECORDER. 2-page Bulletin 604 illustrates and describes maker's "TR-6" turbidity recorder; covers features, applications, various forms of sampling chambers, indicators and recorders.—Ess Instrument Co., Bergenfield, N. J.

S-170 WATER STILLS. 6-page Bulletin No. 910 illustrates and describes maker's "Streamliner" water stills; lists features, applications, capacities; encloses price list.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

S-171 WATER JET EDUCTORS. 36-page Bulletin 2-M describes and illustrates maker's water jet eductors; covers design, construction and operation; special purpose eductors, use in pumping and mixing liquids and handling solids; contains size, dimension and price tables.—Schutte and Koerting Co., 12th and Thompson Sts., Philadelphia 22, Pa.

S-172 SPECIFIC GRAVITY INDICATOR-CONTROLLER. 2-page Bulletin SG-2 describes and illustrates maker's "Gravigage" for indication or control of specific gravity in process industries; covers features, specifications.—Ess Instrument Co., Bergenfield, N. J.

S-173 SQUARE-WAVE GENERATOR. 4-page Bulletin S64-630 illustrates and describes maker's "Type YGL-1" square-wave generator; lists features, specifications; covers principle of operation.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-174 RESISTANCE PERCENTAGE BRIDGE. 2-page Bulletin S-142A pictures and describes maker's resistance percentage bridge for calibration of resistors; covers features, op-

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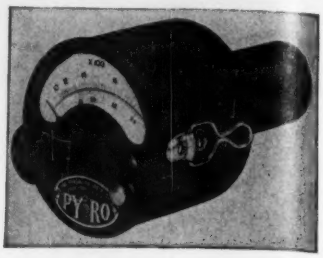

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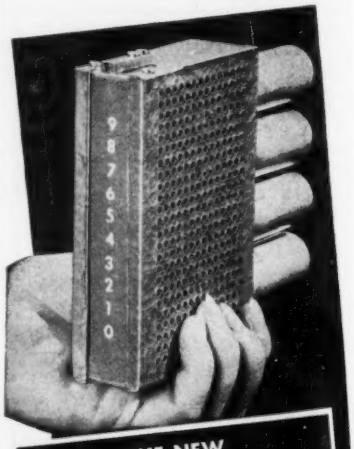

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S-175 AIR DRYER. 2-page Bulletin DD-110 pictures and describes maker's "Model 50-E1AC" dynamic dehumidifier; covers operation, operating data, construction, dimensions and connections.—Industrol Corp., 88-35 76th Ave., Glendale, Brooklyn 27, N. Y.

S-176 FURNACE INDICATOR. 2-page Bulletin 441-B illustrates and describes maker's "Cat's Eye" furnace indicator; covers operation, application.—Ess Instrument Co., Bergenfield, N. J.

S-177 INDUSTRIAL TUBE ANALYZER. 4-page Bulletin S64-533 illustrates and describes maker's "Type YTW-3" industrial tube analyzer for gaseous rectifier tubes; lists feateures, specifications.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-178 TEXTILE UNIFORMITY ANALZER. 2-page bulletin illustrates and describes maker's uniformity analyzer for measuring and recording irregularities in weight per unit length of yarn, roving, and silver; lists uses, advantages, specifications.—The Brush Development Co., 3405 Perkins Ave., Cleveland 14, Ohio.

S-179 CRYSTAL PRODUCTS. 2-page bulletin describes and illustrates maker's crystal products (microphones, headsets); lists advantages, dimensions, specifications.—The Brush Development Co., 3405 Perkins Ave., Cleveland 14, Ohio.

S-180 WASTE ELIMINATION. 16-page booklet, "Solving Industrial Crimes—Case No. 39" describes and illustrates use of maker's recording instruments in locating and eliminating wasteful operations.—The Esterline-Angus Co., Inc., Indianapolis, Ind.

S-181 REGULATED POWER SUPPLIES. 4-page bulletins illustrate and describe maker's regulated power supplies. Bulletin S64-535 on "Model 4ST1A1" 300 volt; Bulletin S64-631 on "Type YPD-4" 1500 volt; Bulletin S64-634 on "Type PS-4" Dual; Bulletin S64-635 on "Type YPD-2" 450 volt; each lists features, specifications, operating principle.—Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.

S-182 ANALOG COMPUTOR COMPONENTS. 4-page bulletin describes and illustrates maker's "GAP/R" analog computor components; covers use, specifications.—George A. Philbrick Researches, Inc., 230 Congress St., Boston 10, Mass.

S-183 POINTER DRAFT GAGES. 12-page Bulletin 122 illustrates and describes maker's straight line bell gages and dial bell gages; covers features, installation, specifications.—Ellison Draft Gage Co., Inc., 215 W. Kinzie St., Chicago 10, Ill.

S-184 UHF MEASURING EQUIPMENT. 4-page bulletin illustrates and describes maker's complete line of UHF measuring equipment (line elements, attenuators, terminations, voltage, power and standing-wave ratio measuring equipment); lists ranges, prices.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-185 MINIATURE CERAMIC DISK CAPACITORS. 2-page bulletin illsutrates and describes maker's "Tiny Mike" miniature ceramic disk capacitors; gives uses, features, specifications.—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

S-186 STRIP-CHART RECORDER-CONTROLLER. 2-page supplement to Bulletin C2-1

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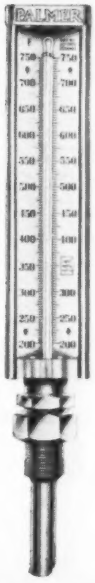

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S-187 "hp JOURNAL." 4-page Vol. 1, No. 6 issue of this house organ features article on maker's "Model 212A" 0.07-10 microsecond general-purpose pulse generator.—The Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-188 "THE OSCILLOGRAPHER." 24-page Vol. 12, No. 1 issue of this house organ features an article titled "Transducers—A Review of the Design and Applications of Transducers for Oscillography"; also included is discussion of maker's "Type 292" cathode-ray oscillograph.—Instrument Div., Allen B. Du Mont Labs, Inc., 1000 Main Ave., Clifton, N. J.

S-189 LIQUID LEVEL CONTROLLER. 2-page Bulletin L-89 illustrates and describes maker's "No. 65" float-operated controller for low water alarm, low water fuel cut-off, etc.; covers specifications, dimensions, electrical ratings.—McDonnell & Miller, Inc., Wrigley Bldg., Chicago 11, Ill.

S-190 PRESSURE SWITCHES. 4-page bulletin describes and illustrates maker's pressure switches for fixed and variable level control of moderate liquid heads; covers design, operation, application, specifications.—Soreng Mfg. Corp., 9555 Eden Ave., Schiller Park, Ill.

S-191 "SCIENTIFIC APPARATUS AND METHODS." 32-page, 1949-50 winter edition of this house organ appears in two sections. Section 1 features articles titled "The Polargraphy of Tin," "High Frequency Chemical Analysis," and picture story on maker's new plant; section 2 covers maker's scientific apparatus (polarographs, laboratory ovens, ultra-violet lamps, (te.).—E. H. Sargent and Co., 4647 W. Foster Ave., Chicago 30, Ill.

S-192 TRIPLE-BEAM TRIP SCALE. 4-page bulletin illustrates and describes maker's triple-beam trip scale with pan and all three beams of stainless steel; covers features, specifications.—W. M. Welch Scientific Co., 1515 Sedgewick St., Chicago 10, Ill.

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ADVERTISERS' INDEX

American Chain & Cable Co. 255
Aluminum Company of America 251
American Instrument Company 253
Ampex Electric Corp. 270
Amthor Testing Instrument Co. 305
Arnold Engineering Company 220
Automatic Electric Mfg. Co. 274

Bacharach Industrial Instrument Co. 307
Bailey Meter Company 211
Barton Instrument Corporation 262
Bell Telephone Laboratories 233
Bendix Aviation Corporation 257, 266, 293
Berkeley Scientific Company 306
Bodine Electric Co. 266
Boonton Radio Corporation 273
Bristol Company 231
Brown Instruments Div., Minneapolis-Honeywell Regulator Co. 222, 258-259
Brush Development Co. 217

Chace Company, W. M. 303
Chatillon & Sons, John 253
Clare & Co., C. P. 224-225
Commercial Research Laboratories, Inc. 273
Conoflow Corporation 298
Consolidated Engineering Corporation 297

Distillation Products, Inc. 214
Durant Manufacturing Co. 294
Dwyer Mfg. Co., F. W. 301

Eclipse Pioneer Div., Bendix 293
Eder Instrument Co. 294
Emery Company, A. H. 268
Eppley Laboratory, Inc. 296

Falstrom Company 212
Field Electrical Instrument Company 274
Fischer & Porter Co. 254
Fisher Governor Company 219
Foxboro Company 216
Friez Instrument Div., Bendix 257

General Radio Company 209
Giannini & Co., Inc., G. M. 260
Gordon Co., Claud S. 305
Green Instrument Company 272

Hagan Corporation 232
Hammel-Dahl Company Inside Back Cover
Haydon Manufacturing Co. 261
Heiland Research Corp. 268
Heise Bourdon Tube Co. 264
Helicoid Gage Division 255
Hellige, Incorporated 305

Industrial Division, Minneapolis-Honeywell Regulator Co. 291
International Rectifier Corp. 262

Kemp Mfg. Co., C. M. 263
Kieley & Mueller, Inc. 215
Kirk & Blum Manufacturing Co. 271

Lambda Electronics Corporation 272
Leeds & Northrup Company 234
Leslie Company 300
Levin & Son, Inc., Louis 298
Lewis Engineering Company 213
Liquidometer Corp. 292

Manning, Maxwell & Moore, Inc. 289
Marion Electrical Instrument Company 223
Marshalltown Mfg. Co. 302
Measurements Corporation 264
Meriam Instrument Co. 299
Mico Instrument Co. 270
Milsco Mfg. Company 275
Minneapolis-Honeywell Regulator Co. 222, 258-259, 291
Moeller Instrument Co. 295

Ohmite Manufacturing Co. 210

Pacific Div., Bendix 266
Pacific Universal Products Corp. 296
Palmer Thermometers, Inc. 307
Passaic Analytical Laboratories, Inc. 274
Pennsylvania Flexible Metallic Tubing Co. 228
Permo, Incorporated 270
Powers Regulator Co. 227
Precision Thermometer & Instrument Company 304
Precision Tube Company 226
Production Instrument Co. 292
Pyrometer Instrument Co. 306

R-S Products Corporation 230
Rubicon Company 265

Schutte & Koerting Company 221
Servo-Tek Products Co., Inc. 256
Shallcross Manufacturing Company 300
Shore Instrument & Mfg. Co. 306
Sigma Instruments, Inc. 301
Sorensen & Company, Inc. 218
Standard Electric Time Co. 269
Streeter Amet Company 303
Superior Electric Co. 267
Taylor Instrument Companies 276

Telechron Inc. 290

Unertl Optical Co., John 306
Veeder-Root Inc. 290
Wallace & Tiernan Products, Inc. 229
Welch Scientific Co., W. M. Back Cover
Weston Electrical Instrument Corp. Inside Front Cover
White Dental Mfg. Co., S. S. 272

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